RYAN MODEL 520 RADAR ALTIMETER

FINAL ENGINEERING REPORT

1 SEPTEMBER 1963

Prepared Under NASA Contract NAS8-2459
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George C. Marshall Space Flight Center

Ryan Report 52067-1
Final Engineering Report

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I. The program described in this report was directed by the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration. The program was initiated to obtain an accurate altitude measuring instrument for use in the SATURN test vehicles. This instrument is required in order to determine altitude in areas where tracking stations are not available. Contract NAS8-2459, covering the design, fabrication, and delivery of altitude measuring equipment for use in the SATURN vehicle, was awarded to Ryan Electronics in August, 1961. The contract was divided into three phases of work which are summarized below:

Phase I - During Phase I, the contract required the design and fabrication of a breadboard altimeter model, the design of an engineering prototype model, and the documentation of a testing program.

Phase II - During Phase II, fabrication and testing of the engineering prototype was required. Upon approval of the test results, two production prototypes were to be fabricated. One production prototype was to be qualified at Ryan Electronics, and the other to be delivered to Marshall Space Flight Center. During this period, two full scale mock-ups were to be delivered to MSFC.

Phase III - During Phase III, two production units for use as SATURN vehicle flight components were to be fabricated. Also during this period, the final documentation consisting of drawings and brief operating instructions were to be prepared and submitted to MSFC.

A. TECHNICAL APPROACH. The basic technical approach to the design of an accurate altitude measuring system was based upon the accurate measurement of elapsed time between a transmitted pulse and a received pulse reflected from the earth's surface. The time measured between the transmitted and received pulses is available in digital form for recording or for telemetering back to ground stations. The basic requirements of the design included a light weight package which stipulated a fairly low power transmitter. In order to achieve the altitude requirements, and still maintain low power, a range delay tracker was stipulated for use in the Altimeter. All design parameters are very conservative in order to maintain highest reliability. The Altimeter was designed in modular form to permit changes without complete redesign. This design approach also enabled the maximum use of specialized subcontractors who could deliver equipment in the shortest possible time.

1. Design Criteria. The design parameters of the Model 520 Radar Altimeter were selected to provide the precision and reliability required. A detailed study of the reflectivity problems was made to obtain the most careful estimate of expected signal attenuation. Each of the radar system parameters, pulse width, antenna gain, operating frequency, transmitter power, receiver noise figure, and receiver bandwidth were simultaneously optimized for the SATURN mission. The design criteria which evolved from the system study are listed below:

    Fixed beams sufficiently wide to accommodate nominal attitude changes.

    Short pulse sufficiently narrow to provide the required accuracy.

    Low noise receiver.

    High clock frequency to provide the required resolution.

    Maximum economical transmitter peak power.

    Maximum efficiency in signal processing.

    Simultaneously optimized parameters.

    High operational reliability and conservative signal to noise ratio requirements.

    High equipment reliability.

    Conservative design safety margins.

    Operational performance evaluated by conservative reflectivity model.

    Modular packaging.

    Minimum weight.

    Minimum power consumption.

2. Preliminary Considerations. The preliminary design study determined that the Altimeter must be a pulse system to satisfy the joint requirements of a 30° minimum beam width and high precision at high altitudes. The wide beam, short pulse design is characterized by high precision, which is independent of altitude. In order to achieve high precision, the pulse width must be short and the signal attenuation may be expected to be in the order of 153 DB. In order to overcome such large attenuation values, the highest economical value of transmitter power must be achieved and particular care must be taken to achieve low detection noise figures. A reasonable weight was considered for such an altimeter and the maximum economical antenna aperture was used; and then the operating frequency, the transmitted power, and the receiver noise figure were simultaneously optimized. The signal processing circuit was designed to provide high operational reliability at relatively low signal to noise ratios. The signal processing circuit was designed to provide high precision and the required resolution.

3. Pulse Width. The basic factor in limiting the error of a wide beam short pulse altimeter is the pulse width. To achieve the desired accuracy, the pulse width must be as short as possible. However, the high altitude signal to noise ratio will be proportional to the square of the pulse width. The pulse width must therefore be as large as possible, limited only by consideration of a resultant error. Two basic sources of error were considered, receiver noise and the shape of the derivative of the returned pulse leading edge. Early design studies have shown that the signal processing circuit will fluctuate approximately 10% of the pulse width for a reasonable signal to noise ratio. Another source of error is the fact that the shape of the returned pulse leading edge is uncertain because the ocean is not always a homogeneous scatterer. In order to meet the

required accuracy of ±100 feet, a pulse width of 1.0 microsecond was chosen.

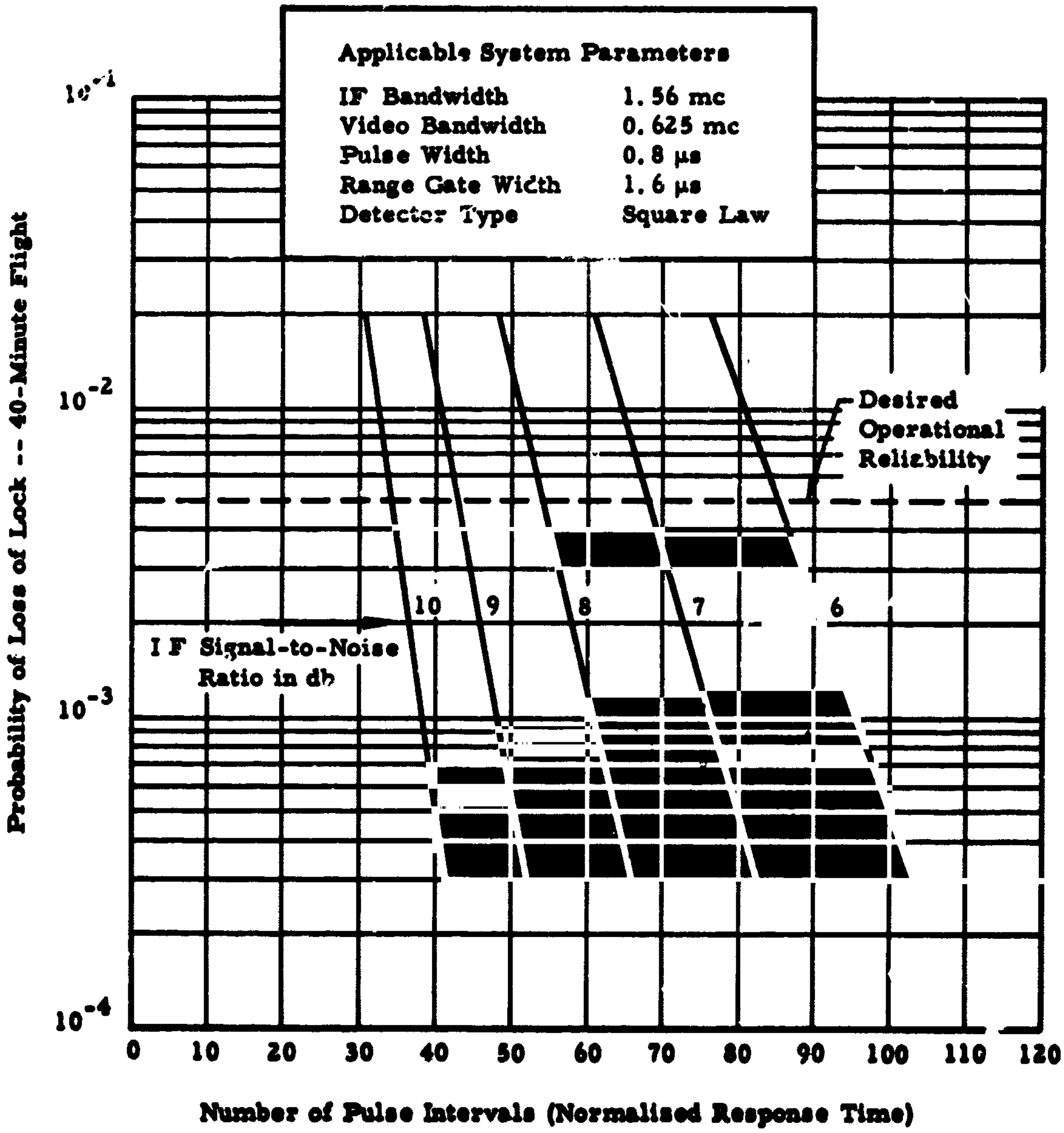
4. Antenna Requirements. The antenna was designed and built by Marshall Space Flight Center, however, the design parameters of the antenna were provided by Ryan Electronics. The following considerations were made in determining the design parameters of the antenna:

The attitude of the SATURN vehicle is to be maintained within ±11° around a known mean attitude. In order to avoid the complexity and weight of a stabilized antenna, a fixed antenna design was desired. Consequently, the antenna beam width must be approximately 30°. This limits the maximum antenna gain to 15 DB. The specific antenna parameters were optimized with other parameters such as transmitter power noise figure and operating frequency. The final proposed design of the antenna provided a gain of 15 DB with a VSWR of 1.25 max. and a beam width of 30°.

5. Reflectivity and Signal Attenuation. Experimental data available on radar return over water is limited to altitudes far below those required for the SATURN Altimeter. Therefore, considerable extrapolation in altitude is required. Data from most available sources has a large spread and agreement between these sources is very poor. It has been very difficult to recognize the correct theoretical reflectivity model among the several that have been advanced. Therefore, Ryan Electronics chose a conservative theoretical model for extrapolation and has compared it with the best available data and determined a reflectivity coefficient which places the model near the lower bound of the mean data value.

6. Signal to Noise Ratio Requirements. The signal to noise ratio requirement for the tracker gate generator is determined by the desired response time and the desired operational reliability. Accuracy is also related to signal to noise ratio, but in the design the accuracy is sufficient for any of the signal to noise ratios considered. Figure 1 shows the calculated probability of loss of lock as a function of the signal to noise ratio and the response time. The standard of reliability was chosen very conservatively to be 5×10^{-3} probability of loss of lock for a forty minute operating time. Also, the design called for a 0.4 second time constant for the Altimeter with a prf of 144 pulses per second. The normalized time constant would be 56 pulse intervals. Consequently, it has been determined that 8 DB is a conservative signal to noise ratio requirement. Practical equipment limitations have determined a signal to noise ratio of approximately 10 DB. This figure still allows a considerable safety margin.

7. Optimum System Parameters. Original design studies of the available transmitter power and achievable noise figure over the frequency band extending from 400 to 2,000 MC indicated that certain points where the equipment weight increase per unit per performance increase is not economical. It was determined that equipment limited in weight to approximately 25 pounds could not reasonably accommodate transmitter power of greater than 10 KW. The practical design objectives for the transmitter power was 8 KW at 400 MC and 5 KW at 2,000 MC, using the GL-6897 oscillator. Noise figures of from 5 to 11 DB for triodes and 7.5 DB for mixers are available in this band. Practical design objectives for the noise figure were approximately 6 DB at 400 MC and 8 DB at 2,000 MC, using a low noise crystal mixer. Considerations were



REQUIRED SIGNAL-TO-NOISE RATIO AND AVERAGING TIME

Figure 1

given to the use of parametric amplifiers but because of the weight increase, this approach was not followed. The required signal to noise ratio, the signal attenuation, the receiver bandwidth, and the various losses due to the duplexer and necessary cabling, were combined to solve for the optimum system parameters. These parameters were determined to be approximately 2 KMC for the operating frequency, 5 KW for the transmitter power, 10 DB for the noise figure, and 15 DB for the antenna gain. The transmitter frequency of 1.61 KMC was assigned by the FCC for use in the Model 520 Radar Altimeter.

8. Digital Output Circuitry. The requirement to provide the altitude in digital form for use in telemetry equipment was a prerequisite in determining basic digital processing circuitry. The basic parameters of the digital processing circuits are the read-out rate, the counting rate, the time stability, and the number of bits. The read-out rate and the binary stability were specified by MSFC. The number of bits were determined from the specified operating altitude, once the counting rate was determined. The counting rate, however, was optimized with other system parameters. The counting rate was designed to be sufficiently high to make the resultant altitude quantization have negligible effect on the equipment performance. Since receiver noise fluctuation account for approximately 50 feet of error, it was determined that quantization values of 35 or 36 feet would satisfy the requirement. The counting rate therefore could be approximately 14 megacycles. For higher resolutions, MSFC required the use of a 20 megacycle counting rate.

B. GENERAL FACTUAL DATA. This section presents deviations of the basic theoretical concept upon which the performance analysis and the Altimeter design were founded. The classical model for Lambert backscattering, the method for calculating the signal to noise ratio requirements and a simplified mathematical study of the Range Tracker are discussed.

1. Lambert Law Backscattering. Radar return by backscattering from an extended surface occurs through the summation of the power scattered toward the receiving antenna by small elements of the surface. The scattering element may scatter in a certain direction as implied by Lambert's Law for which the pattern follows a cosine law with the maximum at normal incidence angle θ and range R is $\frac{P_t G \cos\theta \, dA}{4\pi R^2}$ where P_t is the transmitter power and G is the antenna gain in the direction of angle θ. A fraction K of the incident power is scattered into the upper hemisphere so that the power density at the antenna due to scattering from A is

$$\frac{K P_t G \cos\theta \, dA \, f(\theta)}{(4\pi R^2)^2}$$

Where $f(\theta)$ is the scattering pattern. For Lambert's Law scattering $f(\theta)$ is $4\cos\theta$. (The 4 is required to satisfy the necessary condition that the sum of the energy scattered in all directions be equal to K times the incident energy.) The microwave energy received at the antenna terminals from dA is

$$\frac{4 K P_t G^2 \lambda^2 \cos^2\theta \, dA}{(4\pi)^3 R^4}$$

Assuming a rectangular transmitted pulse shape and a wide beam antenna, the surface area illuminated initially advances in time from a point to a circle of increasing diameter. When the pulse trailing edge reaches the surface the circle reaches its maximum diameter. After this time the circle becomes an expanding annulus including nearly constant surface area. The return power reaches a maximum when the expanding circle reaches its maximum. The incidence angle θ_o subtended by the radius of this circle is given by

$$\theta_o = \text{arc sec}\left(1 + \frac{c\tau}{2h}\right) \cong \frac{c\tau}{h}$$

The peak of the return power is found by integrating over the solid angle defined by 0 to θ_o in incidence and 0 to 2 in azimuth, assuming axial symmetry. Using $dA = R^2 \cos\theta \sin\theta \, d\theta \, d\phi$ where ϕ is azimuth angle, the returned power peak is

$$P_r = \int_0^{2\pi} d\phi \int_0^{\theta_o} \frac{4K P_t C^2 G^2 \lambda^2 \cos^3\theta \sin\theta \, d\theta}{(4\pi)^3 R^2}$$

where $G\lambda^2/4\pi$ is the receiving cross section of the antenna. For θ_o small, G may be assumed constant. Substituting for the altitude $h = R \cos\theta$,

$$P_r = \frac{4K P_t G^2 \lambda^2}{(4\pi)^3 h^2} \int_0^{2\pi} d\phi \int_0^{\theta_o} \cos^5\theta \sin\theta \, d\theta$$

Integrating and using the approximations $\cos^6\theta_o \cong 1 - 3\theta_o^2$ and $\theta_o \cong \sin\theta_o$ gives, finally, for P_r

$$P_r = \frac{K P_t G^2 \lambda^2 c\tau}{(4\pi)^2 h^3}$$

2. Signal to Noise Ratio. The Model 520 Radar Altimeter is capable of acquiring and tracking with a peak return power of -86 DBM or less. This is equivalent, under the worse condition, to a signal to noise power ratio in the IF Amplifier of 14.6 DB. The minimum expected signal to noise ratio at 250 statute miles over sea as shown below is 12.7 DB. The signal to noise ratio in the IF Amplifier is given by

$$S/N = \frac{K P_t G^2 \lambda^2 c\tau}{16\pi^2 h^2 F K T B}$$

K is the Lambert Law scattering coefficient at normal incidence over sea. It is conservatively estimated as 0 DB for high altitudes based on measurements reported by Sandia Corporation. (C. S. Williams, Jr. et. al., "Radar Return from the Vertical For Ground and Water Surfaces" Sandia Coproration Monograph CR-107, April 1960). P_t is the minimum peak transmitter power which is 5.0 KW. The antenna gain, G, is approximately 14 DB at the maximum rated pitch or roll angle (11°). The wave length λ at 1600 megacycles is 0.61 foot, and c is the propagation velocity. The minimum pulse width τ is 0.8 microseconds. The maximum altitude, h, is 250 statute miles or 1,320,000 feet. F is the receiver noise figure, 10 DB, and kT is a constant equal to -174 DBM. The IF bandwidth, B, is a maximum of 3.5 megacycles. Calculation of the minimum expected signal to noise ratio is shown on the following page.

Quantity	Value	Plus DB	Minus DB
K	1.0	0.0	
P_t	5.0 KW Min.	67.0	
G^2	14.0 DB Min.	28.0	
λ	0.61 Ft.		4.2
c	9.835×10^8 fps	89.9	
τ	0.8 μs Min.		61.0
$16\pi^2$			22.0
h^3	1,320,000 ft.		183.6
F	10.0 DB		10.0 DB
kT	-174 DB	174.0 DB	
B	3.5 MA Max.		65.4
		358.9	346.2

Minimum expected S/N at max. altitude: +12.7 DB.

3. Signal Waveform. This paragraph summarizes some theoretical and experimental results pertaining to the return power waveform encountered in pulse altimeters at high altitudes. It is shown that the controlling factor in the return power waveform is the scattering cross section of the terrain as a function of the depression angle $\sigma_o(\theta)$. As this function approaches an inpulse function, the return power waveform approaches the transmitted power waveform corresponding to specular return. If the function $\sigma_o(\theta)$ has a continuous peak at normal incidence, the return power for pulse altimeters may appear to be specular at low altitudes and diffuse at high altitudes. The results expressed above can be shown by means of a generalized function for $\sigma_o(\theta)$. To form a basis for these generalized results some basic equations from the literature are given in Appendix I.

C. DETAIL FACTUAL DATA. The Ryan Model 520 Radar Altimeter has been designed as a high altitude pulse altimeter for use in SATURN test vehicles to altitudes up to 250 statute miles. The Model 520 Altimeter measures range to the reflecting surface by sensing the two way propagation time of narrow microwave pulses between the spacecraft and the reflecting surface. No antenna stabilization is required because the Altimeter is designed for use with a wide beam antenna to provide broad tolerances in pitch and roll. The accuracy of the Altimeter is not degraded by moderate attitude changes, nor by high horizontal velocity. Table 1 below is a condensed specification of the Model 520 Altimeter. The antenna described in the specification is not provided by Ryan as part of the Model 520.

TABLE I

SPECIFICATION FOR RADAR ALTIMETER

Performance	
Altitude capability (over water)	30 to 250 statute miles
Altitude accuracy	±100 feet
Altitude data resolution	25 feet
Altitude capability	+11° pitch, ±10° roll
Vertical rate capability	±25,000 ft. per second
Time accuracy	±10 milliseconds in 10^4 seconds
Time resolution	0.5 seconds
Environmental	
Temperature	-20°C to +75°C
Vibration	10 G's
Shock	20 G's
Acceleration	15 G's
Mechanical	
Mounting	Solid
Weight	25.9 pounds
Size	9-3/4 inches x 9 inches x 11-1/2 inches
Pressurization	5 psig

<u>Electrical</u>

Input Power	80 Watts Max. 65 Watts Average
Input Voltage	26 to 29.5 Volts DC
Warm-up Time	15 Minutes Max.
Transmitter	Type Pulsed Triode Cavity Oscillator
Tube Type	GL-6897
Frequency	1610 Megacycles
Peak Power	5.0 KW Min.
Pulse Width	0.8 to 1.1 Microseconds
PRF	144 pps
Antenna	Beam Width 30°, Gain 15 DB, VSWR (max) 1.25
Receiver	Type - superheterodyne
Noise Figure	10 DB
IF Center Frequency	30 megacycles
IF Bandwidth	3 ± 1 megacycles
Detector Type	Square Law
Range Tracker	Type - Split Gate
Tracking Range	300 to 3000 microseconds
Maximum Tracking Rate	375 microseconds per second
Timer	Type - Gated Clock Counter
Clock Rate	21,233,664 pps.
Clock Accuracy	1 ppm
Altitude Output	Type - Parallel Binary
Number of Bits	18
Sampling Rate (max)	36 words per seconds
Time Output	Type - Parallel Binary
Number of Bits	9
Resolution	0.5 second

1. General Description

The Model 520 Radar Altimeter (see Figure 2) operates on the principle of precision pulse radar ranging. High sensitivity and precision are obtained through the use of the Range Tracker which automatically acquires and tracks the return pulses with a narrow gate, rejecting all but a small section of the noise and interfering signals in the receiver. The Tracker is sensitive to the leading edges of the return pulses, thus insuring the delay time measured corresponds to the perpendicular distance rather than an average of a delay associated with the surface illuminated by broad beam antenna. The Altimeter is divided into basic subassemblies as follows: Timer, Modulator/Power Supply, RF Assembly, IF Amplifier and Range Tracker (see block diagram, Figure 3).

Trigger pulses for the Modulator are generated in the Timer by dividing the clock pulses from 21,233,664 to 144 pulses per second. When triggered, the Modulator pulses the plate of the transmitter tube which generates the five kilowatt pulses at a carrier frequency of 1610 megacycles per second. The output of the transmitter is coupled to the duplexer and then to the antenna port. A sample of the transmitter output is detected by the start pulse detector and fed to the Range Tracker. Echos from the ground picked up at the antenna are coupled via the duplexer to the mixer which is balanced to reduce the effects of local oscillator noise. The mixer is excited by the local oscillator which has a temperature drift characteristic sufficiently near that of the transmitter that an automatic frequency control (AFC) circuit is not required. The IF Amplifier raises the signal level a maximum of 109 DB. The output is normalized by automatic gain control (AGC) to within a few DB of the constant amplitude. The Range Tracker

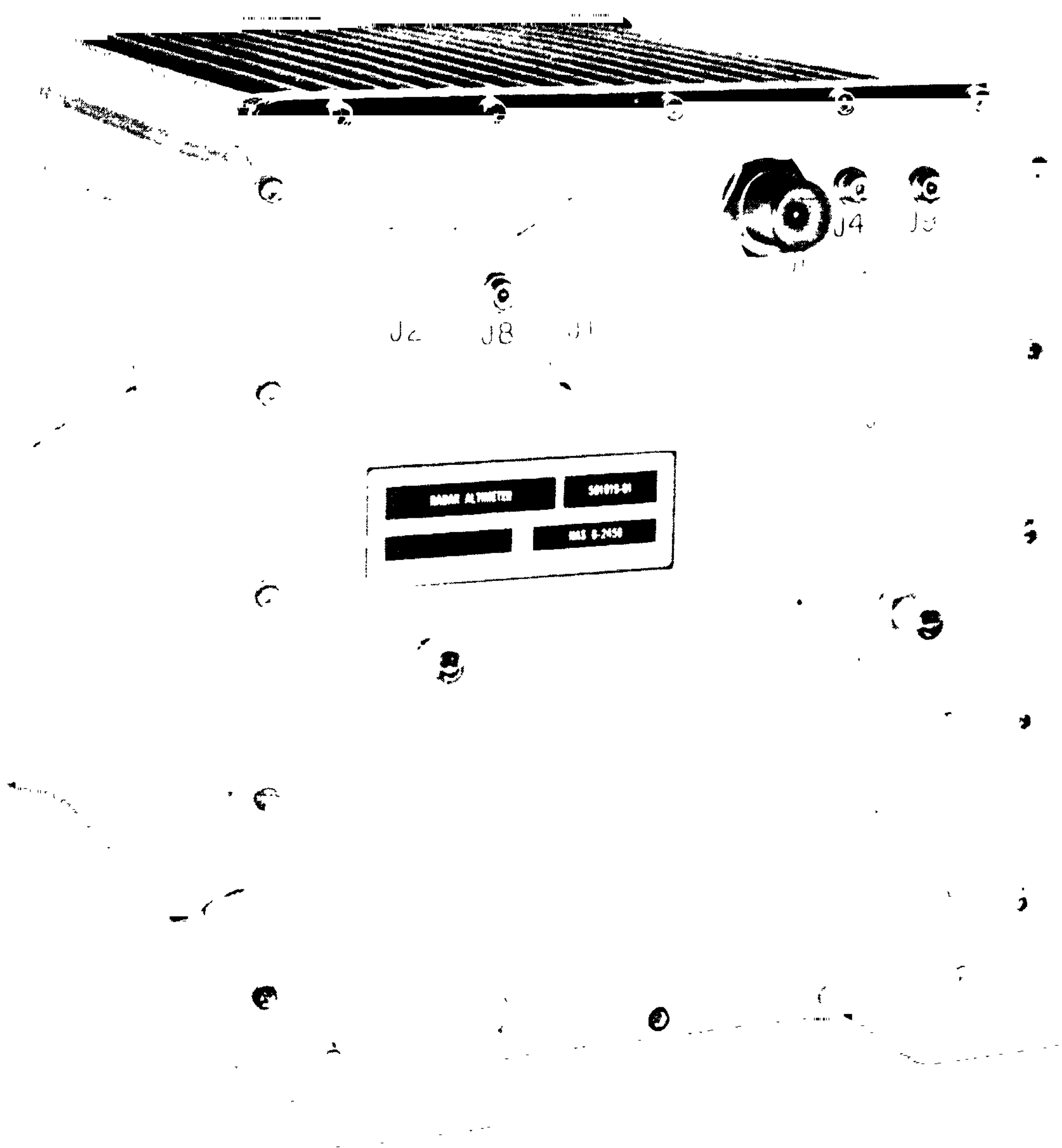
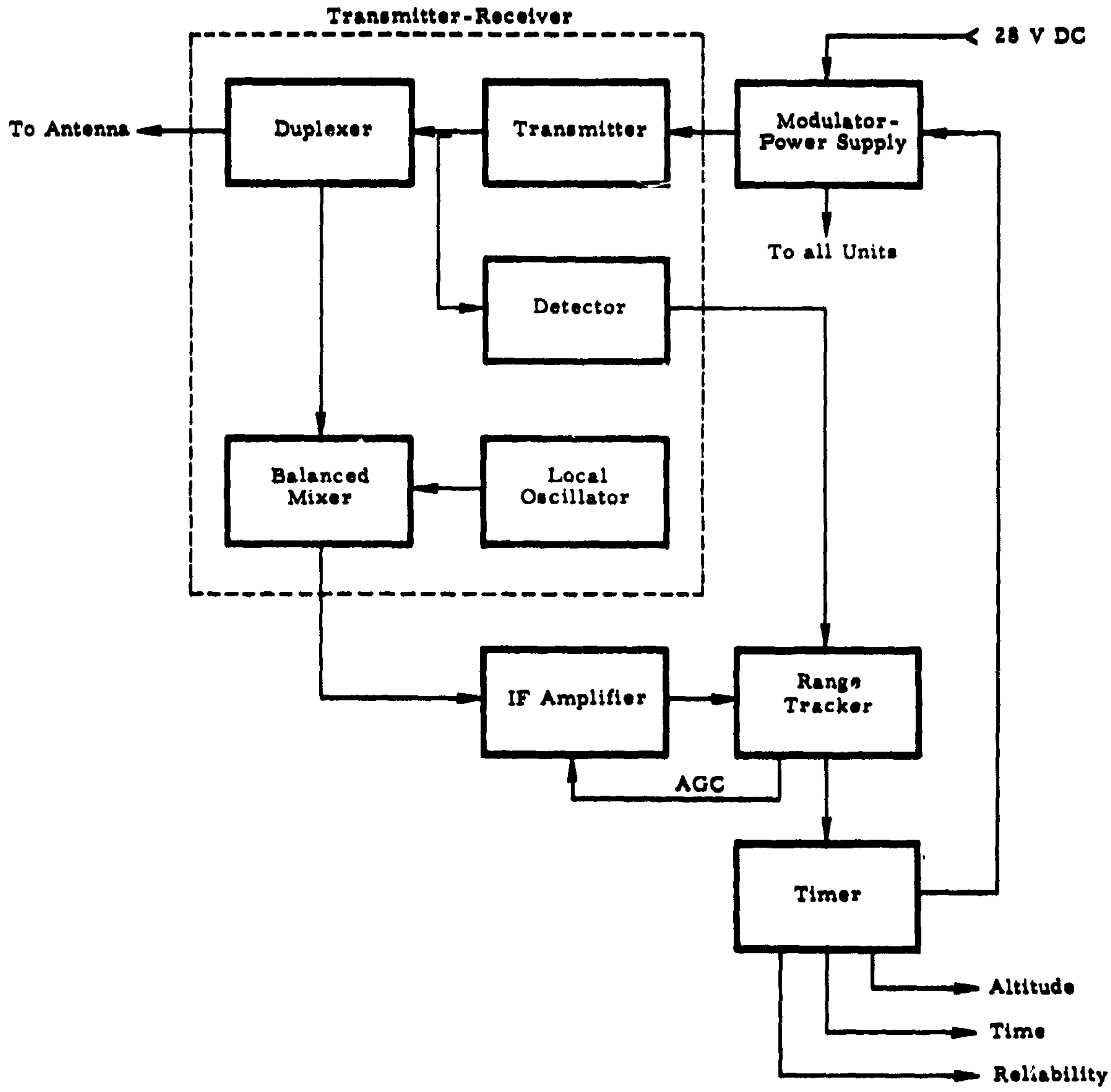


Figure 2. Model 520 Altimeter



BLOCK DIAGRAM
MODEL 520 RADAR ALTIMETER
Figure 3

processes the IF Amplifier output to produce a voltage gate (called the timer gate), which is equal in duration to the delay time of the return pulses. It also provides AGC control to the IF Amplifier. Following detection and amplification in the IF Amplifier, the return pulses are differentiated in the Tracker. The result being narrow pulses coincident in time with the leading edges of the echo pulses. The narrow pulses are tracked by means of a narrow movable gate which automatically follows the differentiated video in time. The tracking gate is generated by means of a feedback loop in which the previously measured delay information is stored. The closed loop effects a considerable amount of smoothing on the altitude data giving a very narrow effective noise bandwidth. Each timer gate is initiated by the start pulse from the transmitter and terminated by the tracking gate. Coincidence of the return pulses and the tracking gate is sensed by a circuit which energizes a relay (signal loss relay) when the two coincide, i.e., when the Tracker is locked on. When the signal and gate do not coincide, the relay opens and the Tracker is placed in a search mode. While in search, the Tracker automatically seeks the signal and locks on when gate-signal coincidence occurs. A loss of lock is highly improbable under normal conditions but is always possible because of vehicle manuevers radical enough to cause loss of signal, temporary loss of primary power, etc. The state of the signal loss relay is made available at the output of the Altimeter in the form of the reliability signal which indicates when the Tracker is "locked-on". The Timer converts the timer gate voltage (from the Tracker) to digital form. The timer gate controls a gating circuit which allows pulses from the clock to pass to a binary counter only for the duration of the timer gate. The counter advances, therefore, by a number proportional to the timer gate during each pulse repetition. After four numbers have been added into the counter, its contents are transferred to an output register from which the altitude output is available in parallel form. The counter is then reset to zero. The time output is obtained by dividing the clock pulse train from 21,233,664 to two pulses per second. The two pps pulse train is counted continuously in a nine bit counter which is connected directly to the parallel time output. The Timer operates without external synchronization of any kind. An "inhibit" pulse of five milliseconds duration is provided at the output when the altitude register is being updated. This prevents the external read-in circuits from attempting to read the altitude during a transfer operation.

2. Program Activities. During Phase I, Ryan Electronics designed and constructed an electrical breadboard model of the Radar Altimeter. A test program relative to electrical checkout, environmental testing and flight testing was developed. Also during this period, a complete prototype model was designed and documented and the documentation and test program was submitted to the Contracting Officer for approval. A description of the design and test problems encountered during Phase I are given below.

   a. Early in Phase I, various subcontractors were surveyed and the following were selected to work on subassemblies of the Model 520 Altimeter:

      (1) Trak Microwave Company submitted an excellent technical proposal and indicated that they could meet the weight and delivery requirements for the RF subassembly. In their proposal they indicated that the transmitter frequency and the local oscillator frequency could be tracked within 0.5

megacycles over the temperature range without an automatic frequency control circuit. For these reasons, Trak Microwave Company was selected to provide the RF Assembly.

(2) LEL, Inc. was selected to provide the IF Amplifier because they could offer an off-the-shelf IF Amplifier with minor modifications to meet the requirements of the Altimeter.

(3) Waugh Engineering Corporation was selected to provide the Timer assembly. This company proposed the use of a Nekay magnetic frequency divider for use in the countdown circuit. The number of components used in the countdown circuit was reduced considerably through the use of this device.

(4) Magnetic Research Corporation was selected to provide the Modulator and High Voltage Power Supply assemblies. Subsequently it was determined that the Low Voltage Power Supply could be incorporated very economically in this assembly. Therefore, MRC provides the Modulator and both Power Supply assemblies.

b. Delay Error Sensor. The delay error sensor is the heart of the Range Tracker and, therefore, this portion of the Tracker was breadboarded very early in Phase I. The delay error sensor was designed to detect the center of gravity of the input or returned radar pulse. Figure 4 is the block diagram of the components that were breadboarded and operated early in Phase I. A Hewlett Packard 212A pulse generator was used to provide a two microsecond pulse. This pulse was used to simulate

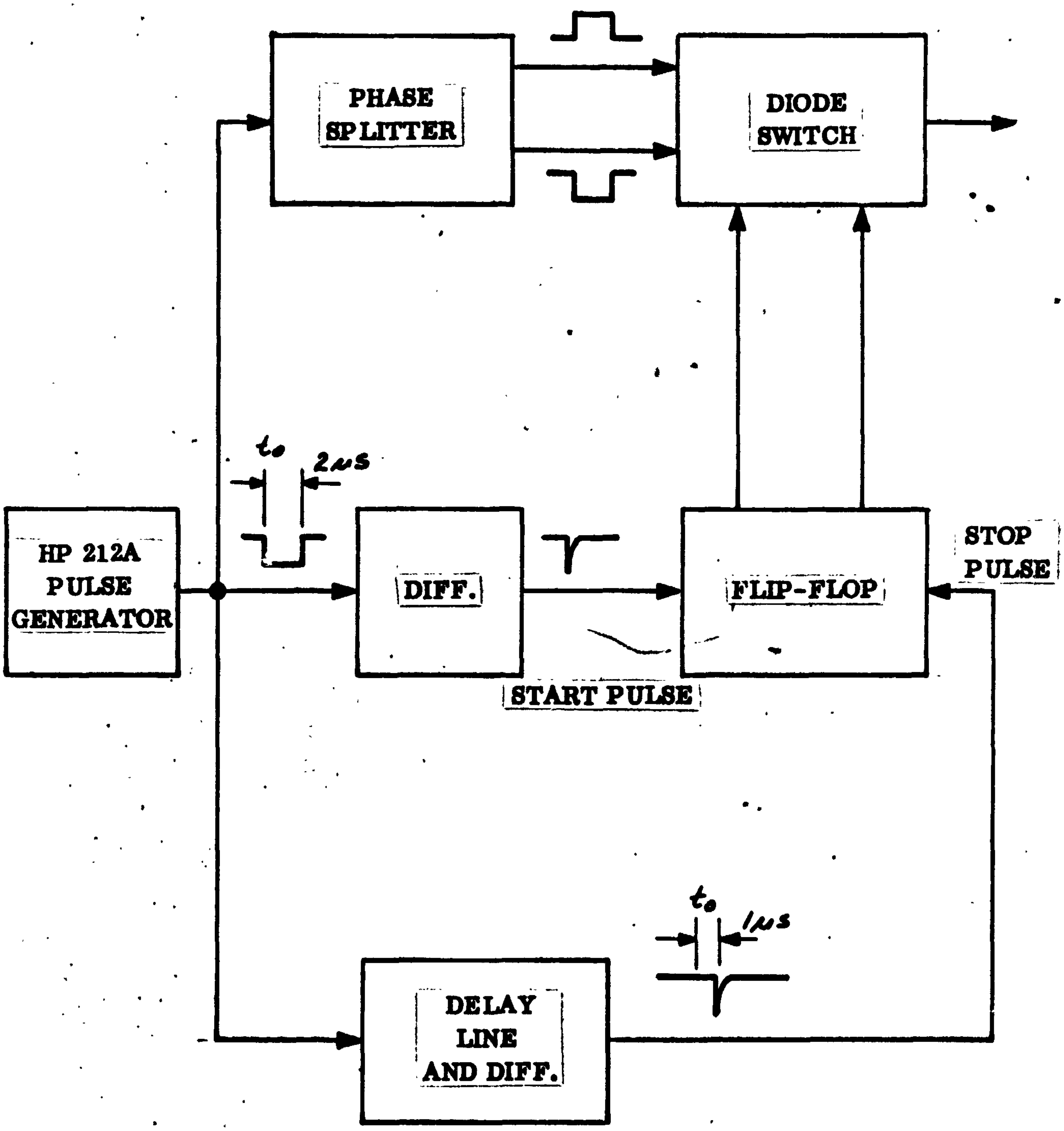


Figure 4. Block Diagram Error Sensor

the actual return radar pulse. A Valor transformer, type 20FB3 was used as the phase splitter. The plus and minus pulses on the output of the phase splitter were used as inputs to a diode switch, which in turn, is controlled by a high speed flip-flop. The leading edge of the output pulse from the pulse generator was differentiated for use as a start pulse for the flip-flop. This start pulse, in the final circuit configuration, was used to start the counter gate. For purposes of evaluating the high speed flip-flop and diode switching arrangement, the pulse out of the Hewlett Packard 212A was also fed to a delay line which provided the total delay of one microsecond. After delay, this pulse was differentiated and the leading edge was used as the stop pulse for the flip-flop. In the final circuit configuration the stop pulse is generated at the time of the center of gravity of the leading edge of the return radar pulse. The center of gravity of the returned radar pulse is tracked by a circuit consisting of a gated amplifier phase splitter, error gate, voltage summing network, pulse generator and flip-flop. If the circuit just described is not on the center of gravity of the return pulse, the diode switch will detect this condition and its output will be either a plus or minus voltage. The output voltage from the diode switch will in turn control the time of occurrence of the pulse from the pulse generator. When a pulse from the pulse generator is occurring at the correct time, there will be a zero output from the diode switch and the center of gravity of the return pulse will be tracked exactly.

c. <u>Preliminary Packaging Studies</u>. Preliminary product design indicated that a cylindrical case would be the most efficient means of packaging the Radar Altimeter. A cylindrical shaped enclosure provides superior use of material which results in a lighter package. Comparisons of various packages, all 600 cubic inches in volume, showed that a nine inch diameter cylinder weighs approximately 1.9 pounds, a 12 inch diameter cylinder weighs approximately 2.7 pounds, and a rectangular case of similar volume weighs seven pounds. During this time, mock-ups of the Radar Altimeter were fabricated as shown in Figures 5 and 6. The five major subassemblies were simulated by wooden block which approximated the final shape and size. Vibration studies of the cylindrical shaped package were begun early in Phase I. The environmental specifications require that the package withstand a vibration environment of 20 to 2,000 cycles per second, from 2 G's to 10 G's. It was determined that resonance of the internal structure would be within the specified vibration spectrum. Therefore, some type of isolation would be required. The cylindrical package was designed so that the mass and isolators would have a resonant frequency of 45 cycles per seconds. The inside bracketry was designed so that it resonated at higher frequencies. The metal mesh isolators were then designed to be placed between the cylindrical package and the rectangular mounting base. The metal mesh isolator would act like a low pass filter and was designed to have a cut off frequency of lower than 45 cycles per second. Tests made on this arrangement, using the metal mesh isolator, showed that the vibration amplitude was reduced from 10 G's to less than 1 G. Later during Phase I, Ryan was informed by MSFC that the Radar Altimeter package must be of a rectangular configuration. After studying various types of rectangular packages, it was decided that a corrugated type wall structure would reduce weight, increase stiffness, and increase heat

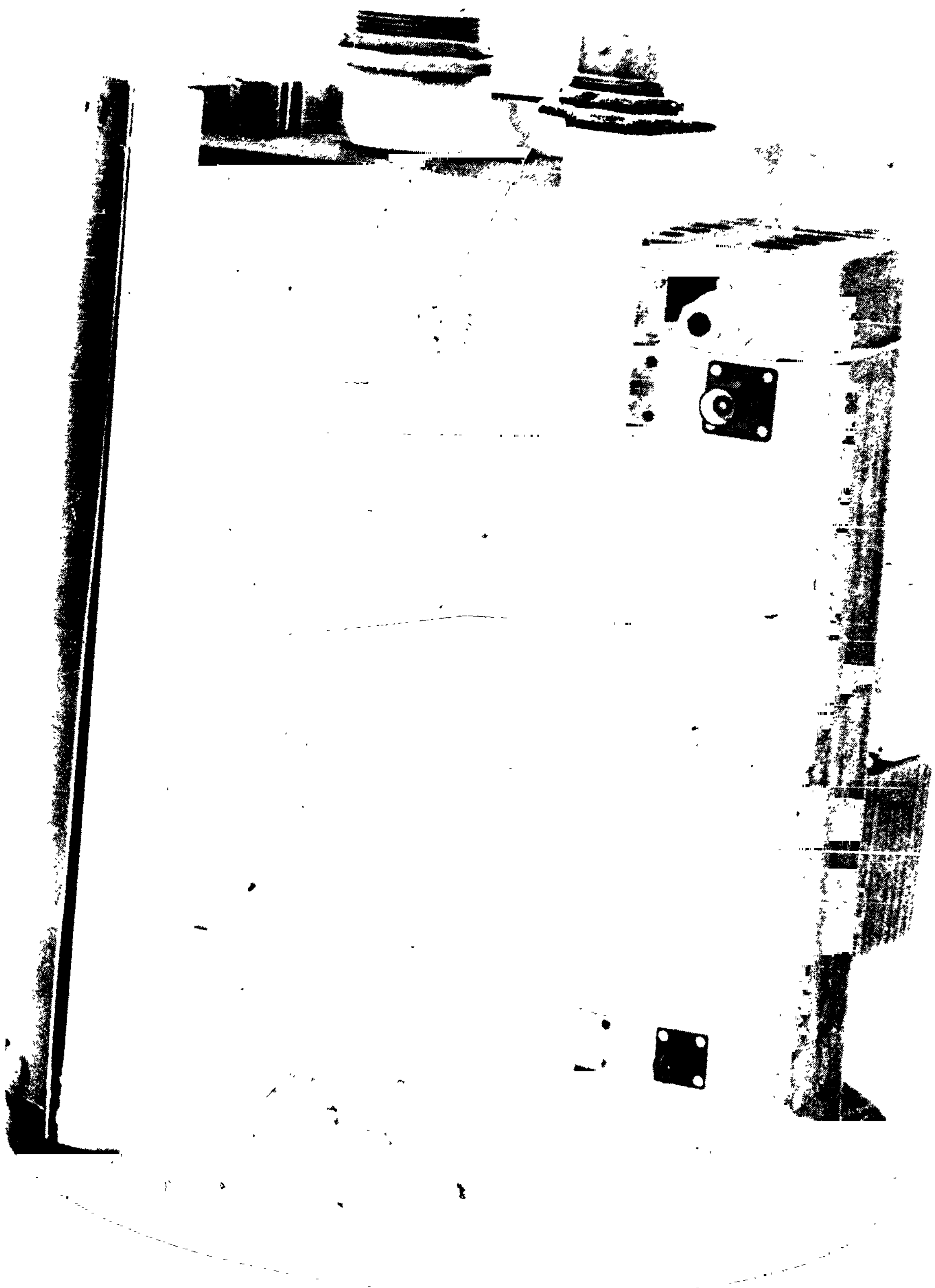


Figure 5. Mock-Up of Cylindrical Configuration.

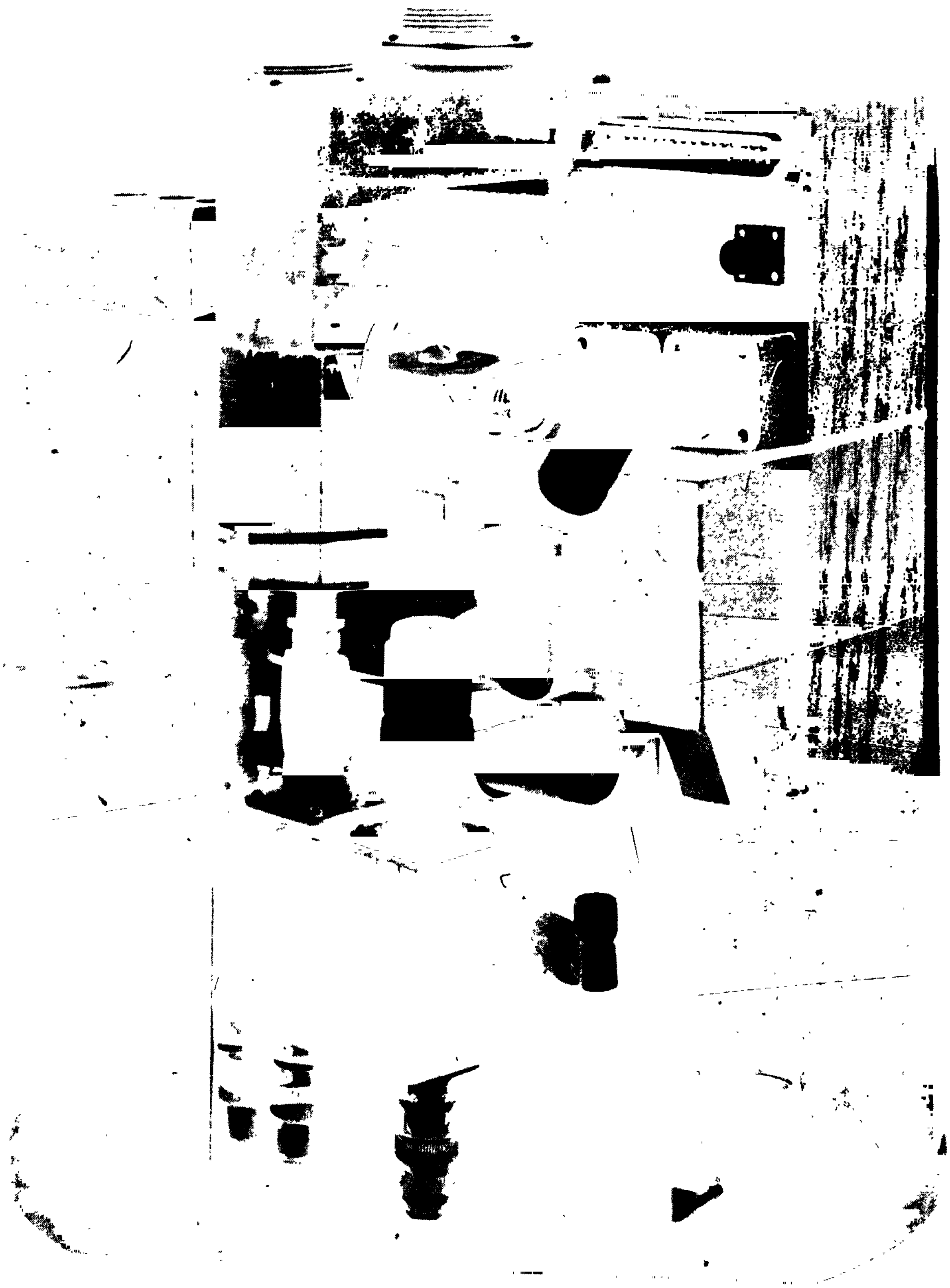


Figure 6. Mock-Up, Cylindrical Configuration.

transfer area. The front and back cover to be a solid material, with ribbing to decrease the weight. Since the Power Supply dissipates the majority of the heat it was decided to mount it close to the bottom half of the front panel. The front panel then acts as a heat sink. Lab tests were set up to determine the temperature drop across the contacting surfaces of the Power Supply and the front panel. A mock-up of the external package was made so that pressure tests could be run. The internal structure was re-designed to fit the rectangular configuration. Product design of the outside case of the Altimeter was continued with the fabrication and test of a dummy case, as shown in Figure 7. The final configuration of the case and chassis is shown in Figure 8.

d. Engineering Prototype Test Results

(1) The engineering prototype RF Assembly was delivered on 25 January 1962. The following data was taken showing that the equipment meets the requirements of the specification:

Electrical Characteristics

Transmitter Power	5.3 KW
Transmitter Frequency	1613 megacycles
Local Oscillator Power	1.8 milliwatts
Local Oscillator Frequency	1583 megacycles
Low Level Receiver Insertion Loss	.9 DB
Leakage Power Transmitter to Receiver Port	70 milliwatts peak
Sensitivity for S + N= 8.0 DB	-98 DBM

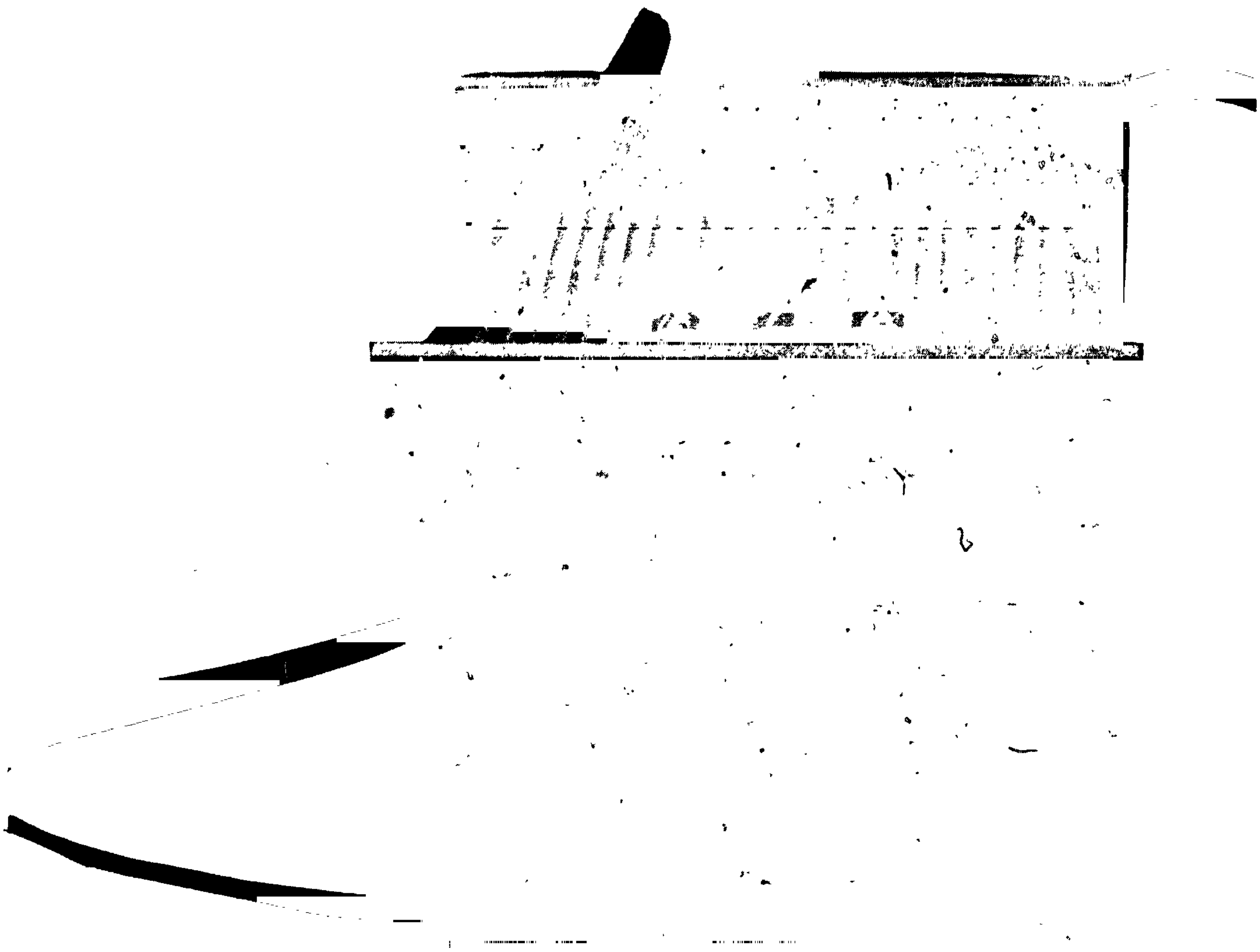


Figure 7. Rectangular Case Mock-Up, Vibration Test.

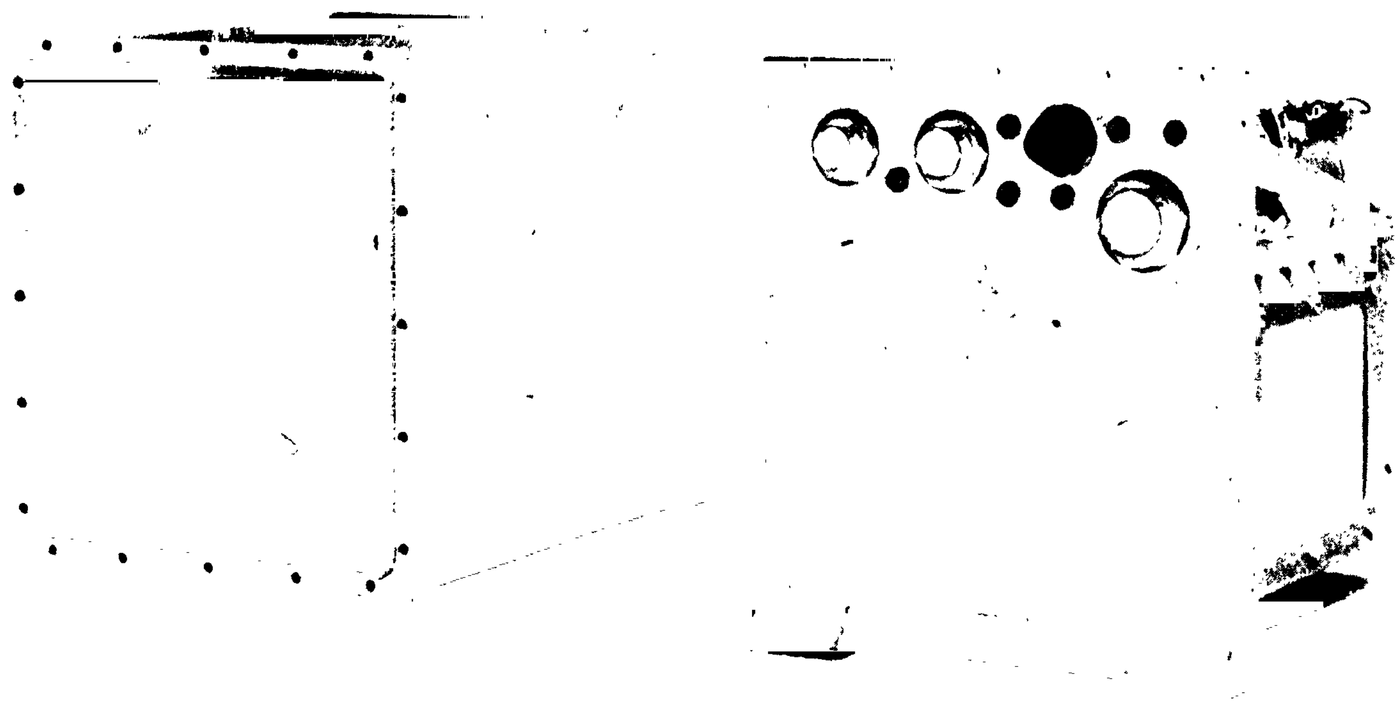


Figure 8. Final Configuration of Case & Chassis.

Temperature Tests (relative drift between local oscillator and transmitter frequency)

TIME	TEMPERATURE	f_{lo}	f_{tx}	f_o
6:18	30°C	--	--	0 MCS
6:40	0°C	+1.0	+0.5	0.5
6:50	-25°C	+2.1	+2.1	0
7:00	-25°C	+2.45	+2.8	.35
7:15	+10°C	+1.2	+1.45	.25
7:38	+30°C	+.1	+0.3	.2
7:50	+50°C	-.8	-0.6	.2
8:00	+75°C	-1.9	-1.5	.4
8:15	+100°C	-3.7	-3.8	.1

(2) The engineering prototype Timer subassembly was given acceptance tests with the following results:

Spec Parameter	Spec Limits	Measured
Clock Frequency	21.233643 to 21.233685 MCS	21.233675 MCS
Output Pulse to Mod.		
PRF	144 PPS	144 PPS
Rise Time	0.2 MS MAX.	0.18 MS
Width	1.5 ±0.3 MS	1.5 MS
Fall Time	0.5 MS MAX.	0.3 MS
Amplitude	5 Volts Min.	5.0 Volts
Inhibit Signal		
PRF	36 PPS	36 PPS
Amplitude	5.0 Volts Min.	5.2 Volts
Width		4.8 MS
Binary Outputs		
Amplitude	0 = 0 Volts	0 = 0 Volts
	1 = 5 Volts Min.	1 = 5.0 Volts

(3) The IF Amplifier subassembly used in the engineering prototype Altimeter was tested with the following results:

Spec Parameter	Spec Limits	Measured
Center Frequency	30 ±0.5 MCS	30 MCS
3 DB Bandwidth	3.0 ±0.5 MCS (later changed to 3.0 ±1.0 MCS)	2.8 MCS
Gain	109 DB	70 to 108 DB
Noise Figure	3 DB	3 DB
Power Requirements	--	+20 Volts, 83 MA -6.3 Volts, 220 MA

(4) Acceptance tests on the engineering prototype Modulator/ Power Supply subassembly provided the following results:

Power Supply

Specified Limits	Measured	Ripple (RMS)
-6.3 ±0.2 VDC	-6.28 VDC	0.036 V
+6.9 ±0.035 VDC	+6.90 VDC	0.020 V
+150 VDC (unregulated)	+147.6 VDC	0.140 V
+5.0 ±0.05 VDC	+4.97 VDC	0.002 V
+20.0 ±0.2 VDC	+20.11 VDC	0.002 V
-20.0 ±0.2 VDC	-20.01 VDC	0.002 V

Power Consumption = 49.7 watts fully loaded

Modulator

Parameter	Spec Limits	Measured
Output Pulse Amplitude	3500 V Min.	3500 V
Output Pulse Width	1.05 ±0.15 µs	1.0 µs
Output Pulse Rise Time	0.1 µs Max.	0.08 µs
Output Pulse Fall Time	0.5 µs Max.	0.3 µs
Ripple	380 V Max.	270 V
Drop	380 V Max.	310 V

Power Consumption = 7.8 Watts

(5) Tests on the Tracker show that the measured average altitude error is +25 feet at -10°C and -14 feet at +95°C, with a signal power of -76 DBM. The maximum occasional random error was ± 80 feet at temperatures between -10°C and +20°C. Above +20°C the maximum error was +45 feet and -70 feet. The Tracker can search and find a signal whose power is -86 DB below one milliwatt. It can continue tracking a signal whose power is reduced to -88 DB below one milliwatt while in the tracking condition. The Tracker can track an altitude range rate of 30,000 feet per second. In five seconds it can search from a 50 kilometer (334 microseconds radar time) to a 400 kilometer range when the signal power is -71 DB below one milliwatt. It takes eight seconds to search and lock on for the same range steps when the signal power is -81 DBM. Search can begin at less than 25 kilometers (167 microseconds radar range). The measured capabilities of the Tracker all exceed the specification requirements.

e. Design of Altimeter Case with Respect to Temperature

Early in Phase II, temperature tests on the Altimeter case were conducted. Dummy units with heaters simulating the actual heat dissipation of the subassemblies were placed in the chassis and case of the Altimeter. Temperature tests of the over-all assembly were then made under the following conditions: Total electrical input was 61 watts with the dummy units, of the equivalent size and weight, each equipped with resistors simulating the correct heat loss. Figure 9 shows temperatures within the case and on the case wall under ambient outside air conditions. With the ambient air at approximately 28°C, the case wall attained a temperature of 44°C; the Tracker, IF Amplifier and Timer subassemblies attained a temperature of 58°C; while the RF Assembly and the Modulator/Power Supply attained a temperature of 60°C. Figure 10 shows the same test with the

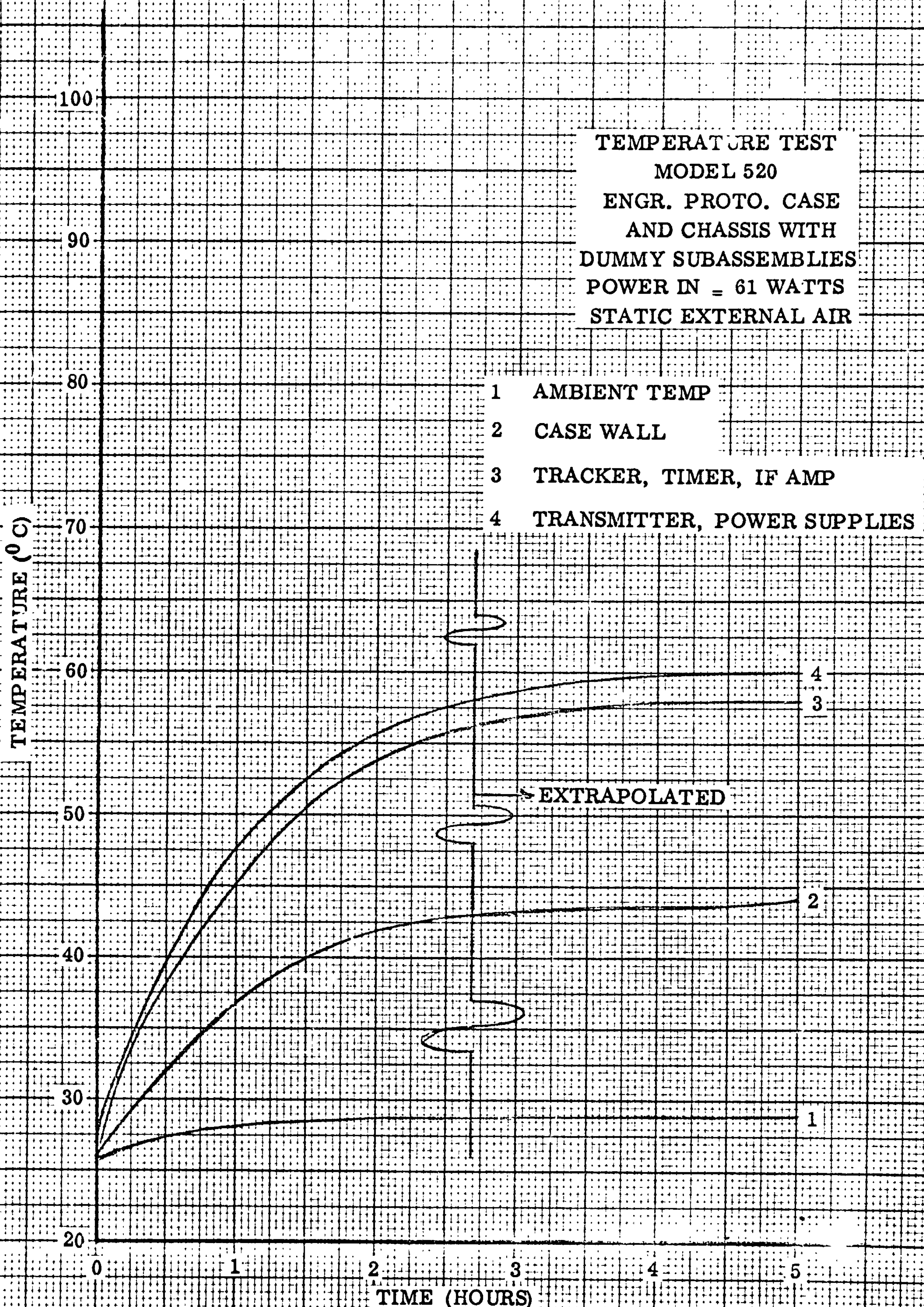


Figure 9. Temperature Test

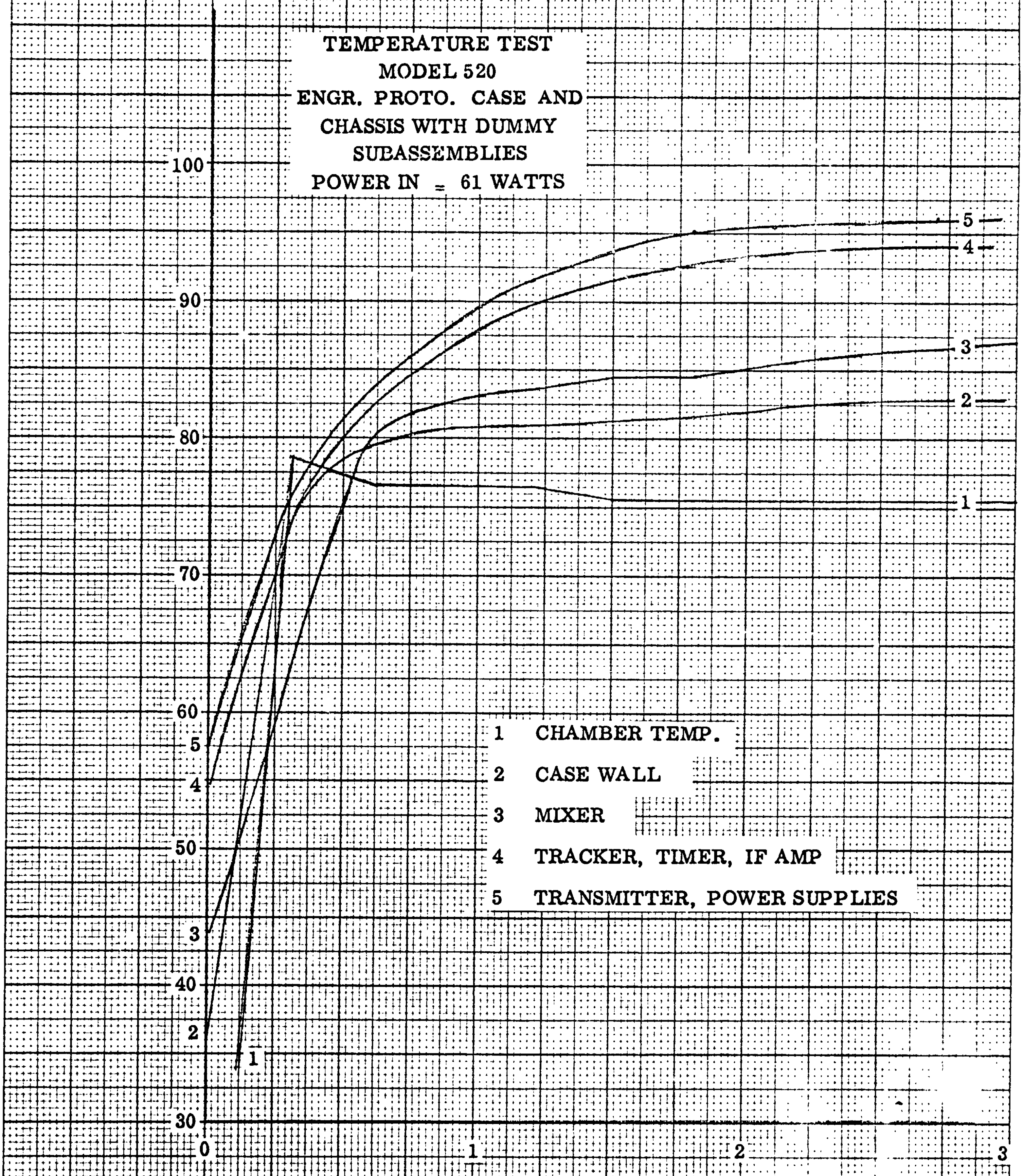


Figure 10. Temperature Test

oven air at 75°C, the upper specified limit. The case wall attained a temperature of 82°C, the Tracker, IF Amplifier and Timer attained a temperature of 94°C, while the RF Assembly and Modulator/Power Supply went to 96°C. Based upon the results of these tests, it was concluded that the design meets the temperature requirement of the specification. Later tests with the actual subassemblies installed and operating under high temperature conditions verified these results.

(f) Special Support Equipment

Special support equipment for the Ryan Model 520 Radar Altimeter is required to provide interconnection between the Altimeter and various items of test equipment for bench testing (see Figure 11). This item of special support equipment provides the following electrical functions:

(1) Indicators

Altimeter power on.

Test set power on.

High voltage ready.

High voltage on.

Reliability signal on.

Neon indicators for each bit of the 18 bit altitude binary word.

Neon indicators for each bit of the 9 elapsed binary word.

Elapsed time indicator for totaling Altimeter on time.

(2) Controls

Test Set power on.

Altimeter power on.

High voltage on.

Selector switch to allow either manual gain control or automatic gain control.

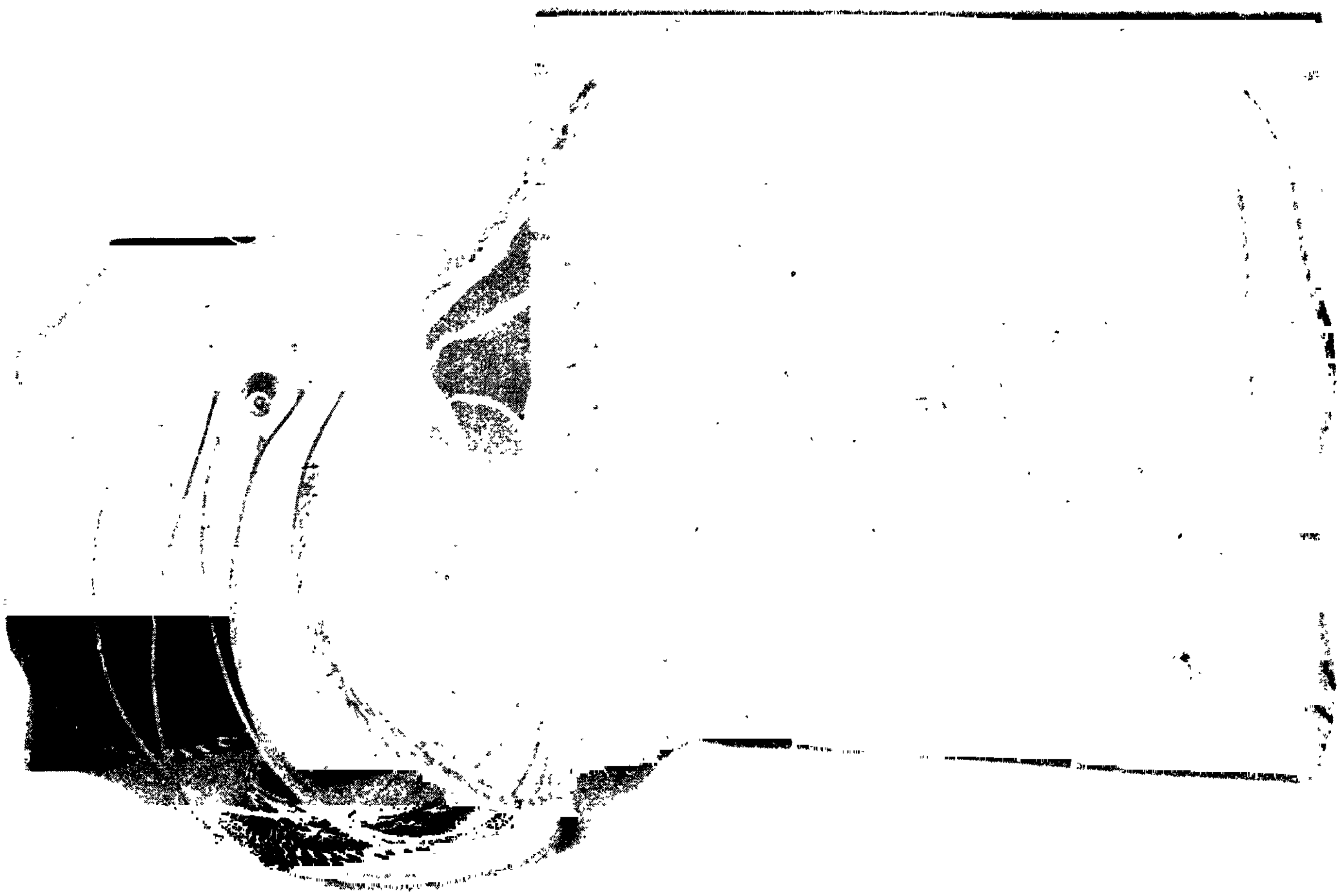


Figure 11. Altimeter & Test Equipment.

(3) Video Pulse Amplifiers

Two video pulse amplifiers are provided for amplification of simulated video signals used in testing the Model 520 Altimeter.

(4) Terminations and Output Jacks

Video detector outputs.
Modulator outputs.
Counter gate outputs.
Transfer pulse output.
Gated amplifier output.
Clock output.
Inhibit signal output.

(5) Pin Jacks

Power supply test signal.
Transmit signal.
Reliability signal.
Filter output.
AGC output.
High voltage on-off.
Power source current and voltage.

In addition to the above items of special support equipment Ryan proposed, but did not build, an item of test equipment to check out the Radar Altimeter while the SATURN vehicle is on the launching pad (see paragraph j).

(g) Confidence and Environmental Tests on Engineering Prototype

Radio frequency interference tests on the engineering prototype showed that the radiated interference requirements of MIL-I-26600 are met on the low frequency end of the spectrum. Shielding of the interconnecting cabling is required to correct high frequency interference. The use of a coaxial cable on the 21 megacycle oscillator output, grounding the case of the oscillator and adding a .01 μf capacitor across the 20 volt DC input to the oscillator corrected the high frequency radiated interference. It was recommended to MSFC that the interconnecting output cables from the Altimeter be shielded. After filtering the input to the Timer assembly and the Modulator/Power Supply assembly, all interference on the 28 volt DC line was eliminated. Pressure tests on the Altimeter case showed that it met the 0.1 pound per hour test requirements. The Altimeter successfully passed the shock and acceleration tests. It also successfully passed vibration in the vertical plane and in the minor horizontal plane. Continued difficulty in passing the vibration test in the fore and aft horizontal plane led to eventual mechanical changes described below.

(h) Altimeter Dummy Mock-up

Early in Phase II, two dummy mock-ups of the Altimeter were fabricated and shipped to MSFC. See Figures 12 and 13. Blocks of aluminum, simulating the weight of the internal structure of the Altimeter, were foamed in place to give the correct weight and center of gravity. These units were provided to MSFC for use in establishing the installation requirements of the Altimeter in the SATURN vehicle.

(i) Proposed Flight Test of the Model 520 Altimeter

A series of low altitude flight tests on the SATURN Altimeter were proposed as part of the current program. The flight test procedure, special support equipment requirements, and data requirements were originated during Phase II of the program. The flight test objectives were: (1) Determination of the steady state performance of the test set-up for various sea conditions at low altitudes. (2) Testing of the correspondence between observed steady state, low altitude performance and calculated low altitude performance based on the criteria used to estimate the characteristics quoted. The correspondence at

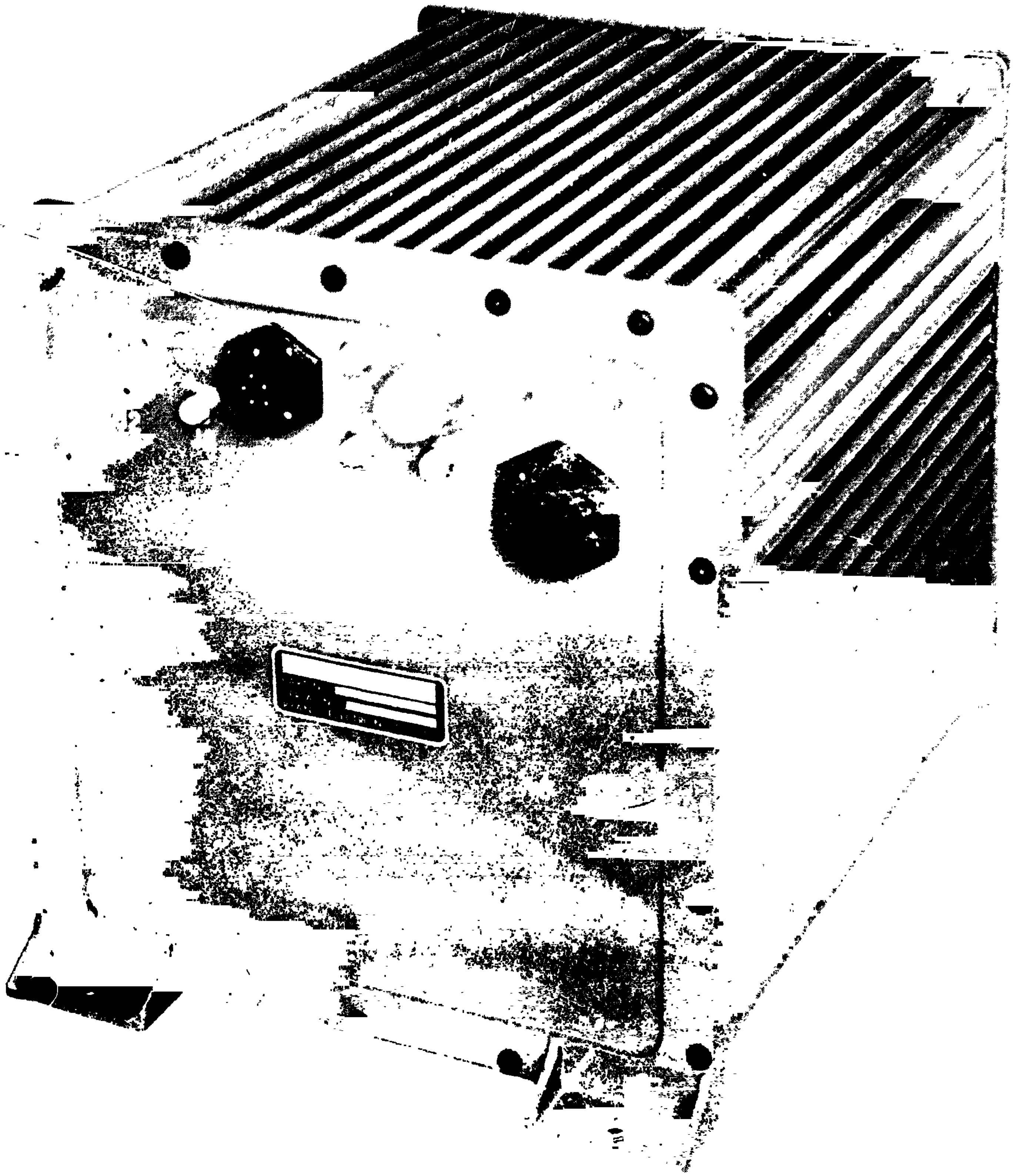


Figure 12. Dummy Mock-Up.

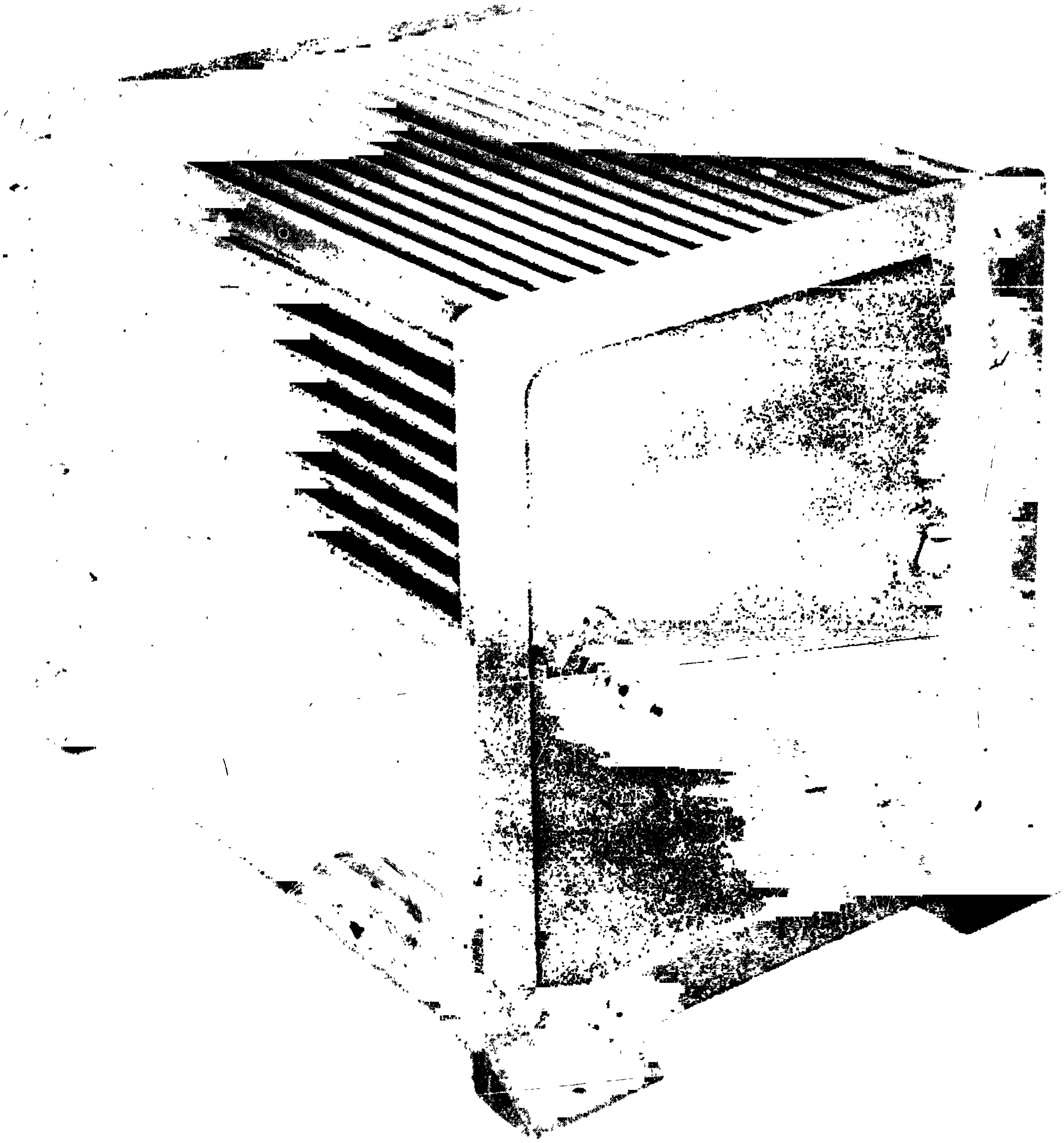


Figure 13. Dummy Mock-Up.

low altitudes would be indicative of the validity of the design assumptions. (3) Observation of dynamic response of the test set-up during ascent and descent for confirmation of desired response for this type of flight profile. (4) Observation of test set-up behavior and nature of the video signal during ascent from 200 feet using a horizontal antenna and noting phenomena which may aid in optiminization of Tracker acquisition circuitry. The test set-up included a modified Altimeter which could be used at lower altitudes, two special antennas which were purchased for the tests, a variable attenuator, a control panel, a dual trace oscilloscope and a six-channel chart recorder with required preamplifiers. The flight test vehicle was planned to be Ryan's DC-3 aircraft. Both antennas were to be installed in the aircraft, so that the specified antenna parameters for the Model 520 Altimeter would be maintained. With the wide beam, down looking antenna connected, the test set-up would approximate the Altimeter installed in the SATURN vehicle with an altitude capability scaled to 10,000 feet altitude. With the narrow beam, forward looking antenna connected and 0 DB attenuation, the operation of the test set-up would be equivalent to the SATURN Altimeter as the vehicle leaves the launch pad. Detailed data requirements were set up and the entire flight test documented. However, the flight tests were cancelled because of program schedule difficulties. A separate program was set up by MSFC through Auburn University to obtain experimental data on signal return at high altitudes over various types of sea conditions.

(j) Contract Redirection

A meeting was held at MSFC between the Contracting Officer, technical coordinator and representatives of Ryan Electronics in June, 1962 to determine the best method of incorporating certain contract changes. The contract was revised as follows:

(1) Phase II was extended to include the manufacture of four production prototypes. Final delivery of these units to be made by 11 October 1962. Bench acceptance tests were to be run on each of these production prototypes prior to shipment from Ryan. Environmental testing was to be accomplished at MSFC on the first production prototype.

(2) A new Phase III to continue from the end of Phase II to allow the add-on production of five Altimeters. These Altimeters to be acceptance tested by Ryan and delivered to MSFC for final testing.

(3) Final documentation, including the handbook and final engineering report to be delivered by Ryan during Phase III.

(k) <u>Launch Site Test Set</u>

Discussions with MSFC personnel revealed a need for an Altimeter launch test set. During Phase II, Ryan provided a general description of a proposed launch site test set for the SATURN radar Altimeter. This description was included in a formal proposal submitted to MSFC. Figure 14 shows the proposed method of positioning test equipment at the launch site. It is assumed that the Altimeter antenna is turned away from the block house when the SATURN vehicle is on the launch stand. Therefore, the transmit pulse from the Altimeter is toward antenna #1 mounted on the gantry, but in a position which allows it to re-radiate the Altimeter transmit signal to antenna #3 located on the block house. The signal received by antenna #3 is sent to a transponder located within the block house. Figure 15 is a block diagram of a proposed

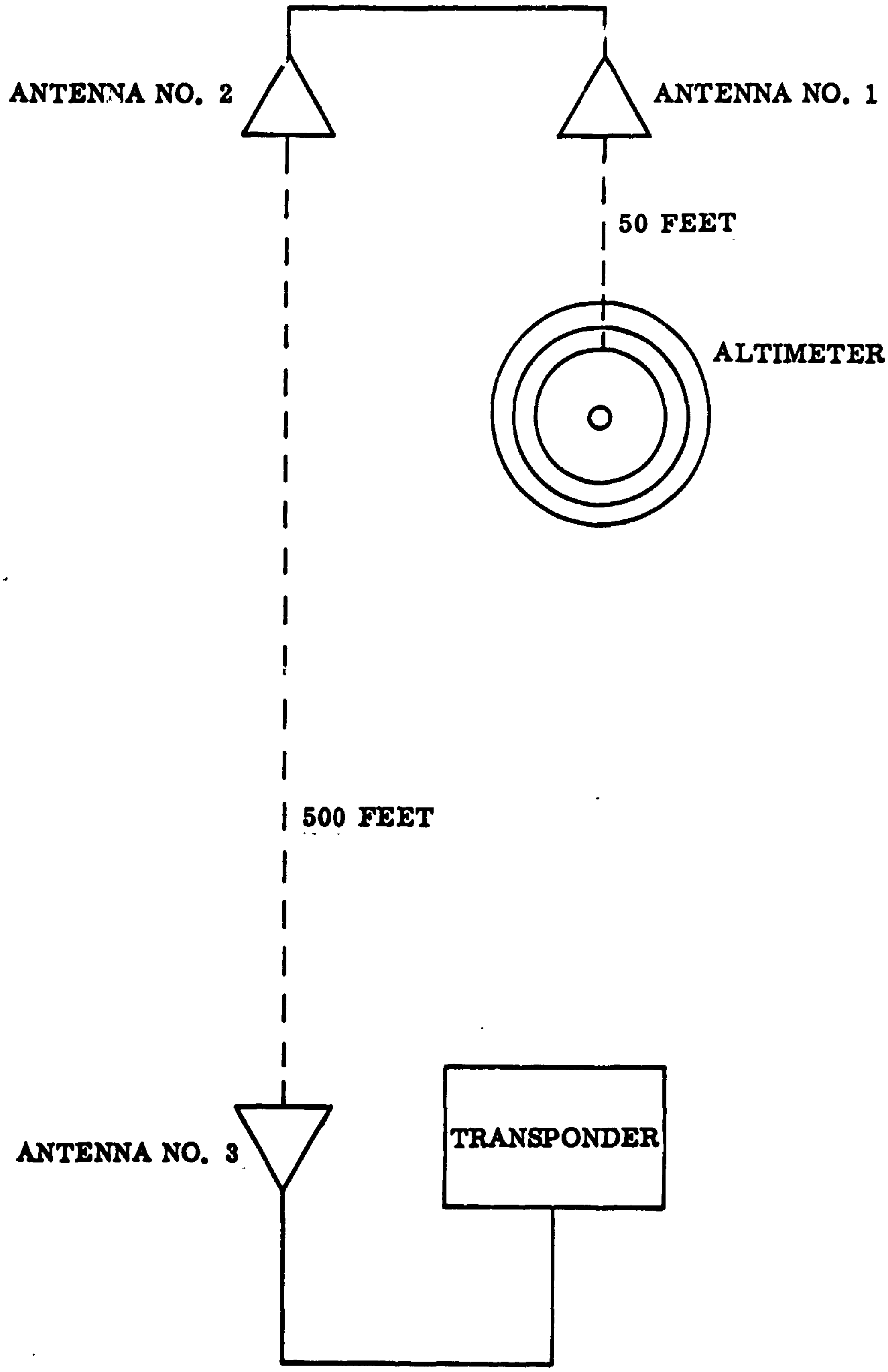


Figure 14. Launch Site Test Setup

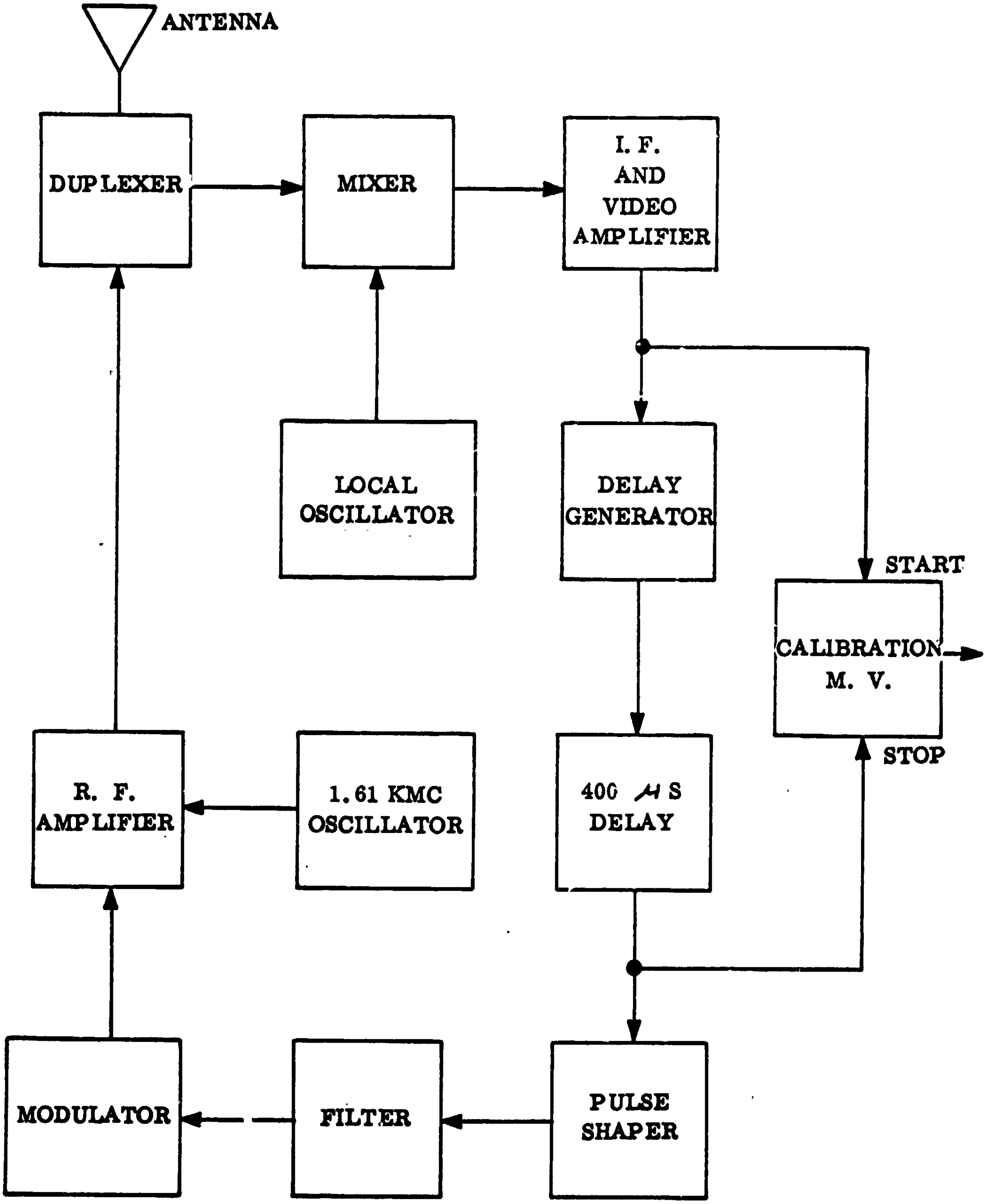
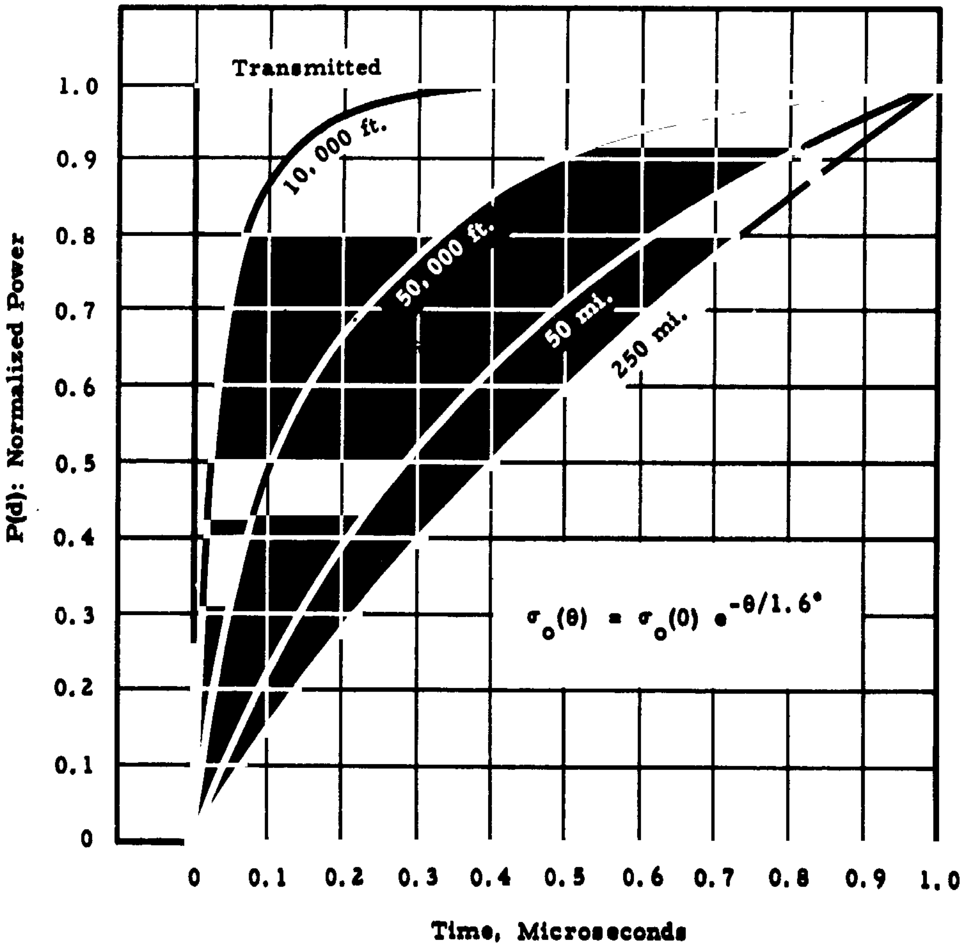


Figure 15. Launch Site Test Equipment, Block Diagram

transponder. The signal is processed through a duplexer, mixer, IF amplifier, and video amplifier which are all similar to components used in the Model 520 Altimeter. The delay generator (Model 520 Altimeter type monostable multivibrator) is triggered by the video pulse. A delay of 1,000, 2,000, 3,000 or 4,000 microseconds may be selected. The trailing edge of the delay generator output signal is then used to trigger a simulated radar return pulse generator consisting of the 400 microsecond delay linear sweep generator and filter. The simulated signal is then used to amplitude modulate a 1.610 KMC signal which is fed back through the duplexer and transmitted from antenna #3. A monostable multivibrator is used in the transponder to provide means for calibrating the delay generator. The simulated radar return signal is then returned to the Model 520 Altimeter via antennas #2 and #1. The Altimeter measures the delay between transmit and received signals and provides the answer to telemetry transmitters. The telemetry transmitter will relay the Altimeter information to the blockhouse where it can be checked for accuracy. If a 10 DB attenuator is used over the Altimeter antenna and the distance from the Altimeter antenna to antenna #1 is approximately 50 feet, and the distance between antennas #2 and #3 is 500 feet, the power required from the transponder transmitter is 100 milliwatts. All antennas to have a 15 DB gain. The minimum height of antennas above the ground should be about 12 feet to eliminate side-lobe interference.

(1) Return Pulse Waveforms

Initial tests on the Model 52 indicated that the Altimeter was very dependent upon the shape of the simulated return radar pulse. Because of this fact, and also because flight tests were inconclusive, a further analysis of the return wave shape was conducted by Ryan. The results of this study were presented in Ryan Report No. 52071-6. A summary of the conclusions reached in this report are shown in Figure 16. Figure 16 is a graph of a family of theoretical return pulse wave shapes. At very high altitudes (250 miles), the rise time of the return pulse is equal to the pulse width of the transmitted pulse. Rise time decreases as the altitude decreases. The report also states that the curves of Figure 16 represent average wave forms and that individual pulse wave forms will differ appreciably from this average. It is also mentioned in the report that the wave forms are altered by the response of the receiver. In the case of the Model 520 the rise time will never be shorter than 0.25 microsecond due to the bandwidth of the IF Amplifier. The Altimeter is designed to track the center of the rise time of the return pulse. Therefore, at lower altitudes, the Tracker will tend to track a point earlier in time. At higher altitudes, the Tracker will tend to track a point towards 0.5 microsecond or the center of the one microsecond pulse. It can be seen that the accuracy of the Tracker will vary depending upon the rise time of the return pulse or the altitude of the Altimeter. Since the return pulse wave front can vary from the rise time of 0.25 microsecond to one microsecond, the tracking point can vary as much as 0.4 microsecond. This variation represents an error of ±100 feet. Because of this variation in accuracy, a re-design of the Tracker input circuitry was accomplished during Phase II of the program. The input circuit was changed from an RC type to an LRC type which resonates at approximately 0.5 megacycles. This circuit receives input signal wave forms with rise times of 0.2 to one microsecond and produces an output square wave of one microsecond into the Tracker. Through the use of this circuit, variations in return pulse wave forms were no longer a problem to the Altimeter. Also, since a constant one microsecond pulse is continually presented to the Tracker, the accuracy of the Altimeter does not vary with altitude.



NORMALIZED POWER WAVEFORMS
Figure 16

m. IF AMPLIFIER GAIN - AGC - TEMPERATURE. During temperature testing of the Altimeter it was determined that the gain - AGC curve of the IF Amplifier varied with temperature. The over-all gain - AGC curve of the production IF Amplifiers varied by as much as 12 DB from one IF Amplifier to another. This variation in gain-AGC curves could not be compensated by the adjustment range of the AGC circuit of the Range Tracker. Specifications for the gain-AGC curve of the IF Amplifier were tightened and all of the IF Amplifiers returned to the vendor for modification. Extensive changes were made to the IF Amplifiers and the resultant gain-AGC curves are shown in Figure 17.

n. VIBRATION REQUIREMENTS. The original vibration requirements for the Model 520 were as follows:
"The Altimeter shall be capable of withstanding a sinusiodal vibration in each of its three major axis without adverse effects on its operation. The vibration frequency shall be swept from 10 to 2,000 CPS to 10 CPS in 15 minutes (sweeping twice on each of its three major axis, noting the frequency of all resonant points) for the following conditions: 20 to 50 CPS at 2 G's, 50 to 110 CPS at .016 inches double amplitude displacement, 110 to 2,000 CPS at 10 G's. Each resonant frequency noted above shall then be subjected to 10 minutes vibration in each of the three major planes at half the above amplitudes." A change to the above testing procedure was [illegible] early in the environmental testing on the first production Altimeter. The new vibration requirements included a random noise input of 12 G's amplitude for three minutes. After subjecting the Altimeter to this vibration, an input random noise of 7.5 G level for seven minutes was required. Difficulties in meeting the vibration requirements led to extensive modifications of the Model 520 Altimeter and subsequent installation of these modifications in all Altimeters.

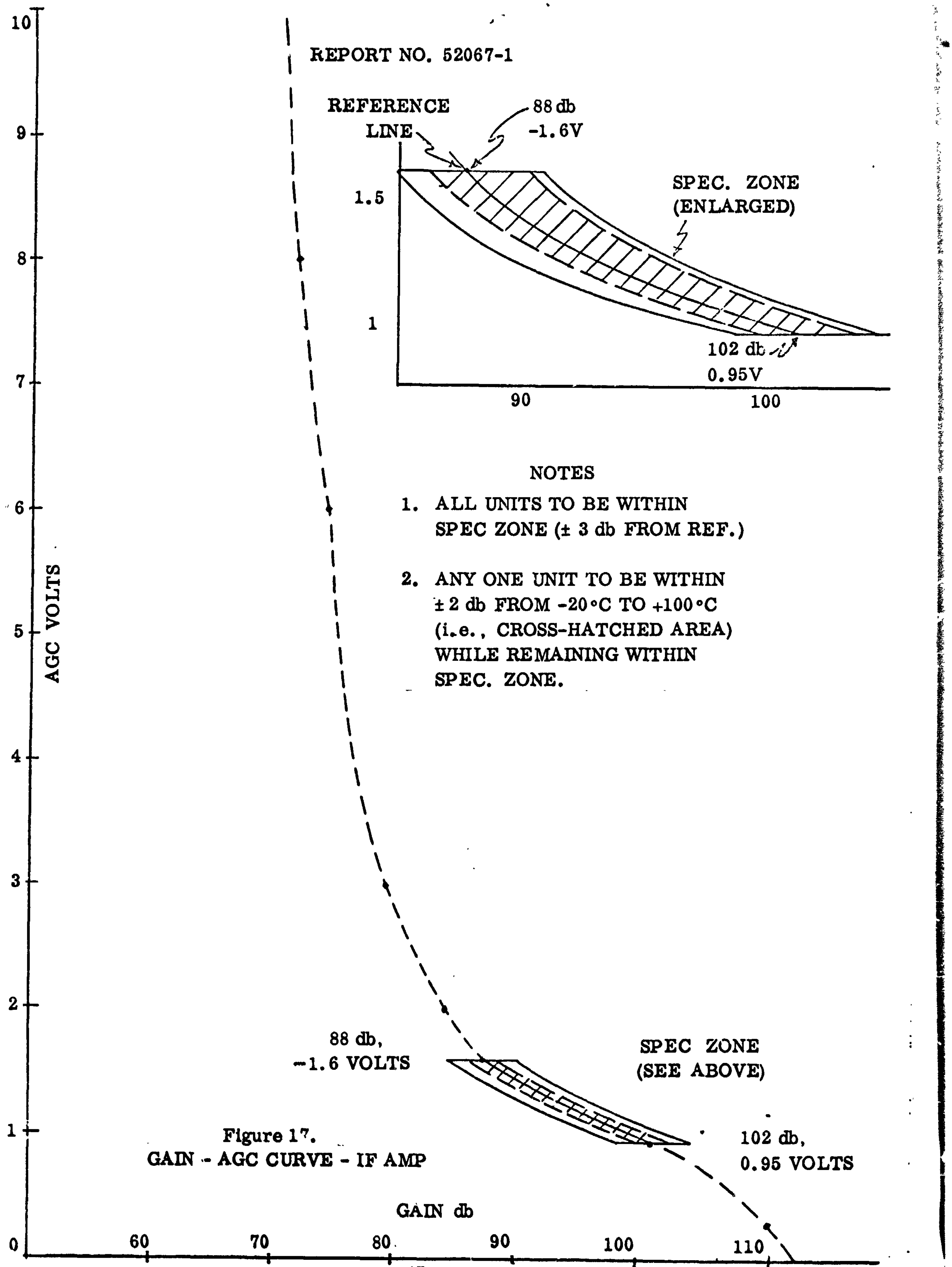


Figure 17.
GAIN - AGC CURVE - IF AMP

o. <u>RELIABILITY INVESTIGATION.</u> The following major reliability investigations were made during the program:

(1) An investigation into the deterioration of mixer crystal diodes was initiated because of the several failures that had occurred. Studies of the waveform and average power of the transmitter feed-through pulse indicated that the power level is well below the crystal burnout level. The output of the local oscillator is normally in the neighborhood of 2 milliwatts. This level is also well below the minimum burnout level of the crystal mixer diodes. The 1N21EMR crystal diodes have a 5 erg burnout rating, which allows a safety margin of approximately 2-1/2 ergs. An alternate crystal, type MA4172AMR, was suggested because it has a comparable noise figure and a burnout rating of 10 ergs. The crystal deterioration problem was later minimized by careful attention to RF assembly calibration. Therefore, the 1N21EMR crystal diodes were continued in use until the type 1N21FMR crystals became available. The 1N21FMR crystals are now being used because they provide between one half and one DB of noise figure improvement.

(2) Because of the several failures of the 21 megacycle oscillator manufactured by Delta F Inc., a quality control investigation was made. The results of the investigation are given below:

Oscillator S/N 794-1 was removed from its case and the potting compound removed from the assembly board for general evaluation. The following items of poor workmanship were observed:

(a) Solder flux not cleaned from terminals, parts or mounting board prior to potting.

(b) Fiberglass board burned during soldering.

(c) Improper bend radius on several components.

(d) Several component leads exceed the 180° wrap on terminal posts.

(e) Top insulating heads appear to be carved out with a pocket knife.

(f) The inner container cover was not screwed in place. Both screws were missing.

(g) Screw hole inside of the external can negates hermitic seal.

(h) Evidence of corrosion around header on inside of cover.

(i) Very poor soldering on header and the entire circuit board. The general soldering of this unit is not acceptable for space systems as established by basic NASA standards.

(j) Several leads are too close to terminal posts, transistor bodies, etc.

(k) Small pieces of loose solder were found in the can and stuck to the mounting board.

The general workmanship noted in this unit indicates that it is scrap and not suitable for use in space systems applications. This or similarly manufactured units are not considered acceptable for space systems use. A detailed examination of the basic NASA space systems requirements should be made by this company. It is understood that this unit is not a shelf item but manufactured to a Waugh spec control drawing and as such should meet all the basic space system requirements for the manufacture of such a unit. A Ryan Quality Control Representative was sent to Delta F to inspect manufacturing of two oscillators and inspect the repair on a third oscillator. The report from the Ryan QC representative included the following information:

"The mechanical design of the oscillator is similar to a breadboard configuration. There were no drawings available to show parts layout and the parts were placed haphazardly on the board. Investigation of the 21 megacycle oscillator which failed during vibration showed that a tuning slug had moved in one of the tuned transformers causing a loss of output. The workmanship on this unit was very unsatisfactory and Delta F agreed to rebuild the entire unit."

Delta F. Inc. was not recommended as a future supplier of the 21 megacycle oscillators. On following procurement of this item Waugh Engineering Company obtained the 21 megacycle oscillators from Monitor Products Co.

(3) A measurement of the noise level on the 6.8 VDC line of Altimeter S/N 1 revealed that it was approximately 70 times higher than the noise on the output line of the breadboard power supply. The only difference between the two units appeared to be the type diodes used in the rectification and regulating circuitry. Altimeter S/N 1 is required to use Mil Spec diodes which supposedly are direct replacement for the commercial variety diodes used on the breadboards. When the Mil Spec diodes were installed in the breadboard power supply, the same high noise condition as obse ... When the breadboard diodes were installed in Altimeter S/N 1 the noise condition was eliminated. As a result of these tests, a modification program was accomplished to make the following changes in components of the power supply:

(a) Three type 1N2536 diodes were replaced by type 1N2512 diodes.

(b) Two type HR1G001 diodes were replaced by type DI648 diodes.

(c) Eight type HR1C002 diodes were replaced by type DI645 diodes.

(4) Continued damaging of varactor diodes and mixer diodes (see paragraph o.(1) above) led to an investigation of the RF Assembly. The RF output probe locking collar assembly did not securely tighten the RF probe. A redesigned collar clamp was placed on the output probe which eliminated the problem of variation in output frequency which had caused damage to varactor diodes and mixer diodes.

p. A meeting was held at MSFC on 13 February 1963 between representatives of the MSFC Contracts Department and Engineering Department along with representatives of Ryan Contracts and

Engineering Departments. The meeting was held to discuss the estimate to complete the SATURN Altimeter program. The schedule required for the follow-on five Phase III Altimeters was reviewed and requirements determined as follows:

One Unit 15 June 1963.
One Unit 1 July 1963.
One Unit 1 August 1963.
One Unit 15 August 1963.
One Unit 1 September 1963.

Delivery as required above was acceptable based upon extension of existing waivers. MSFC representatives required the following general changes in the five Altimeters:

(1) The ABMA-STD-428B requirements for gold plating printed circuit boards was added.

(2) Redesign the power distribution board.

(3) Use terminals instead of lugs in the power supply if possible.

(4) Provide two air valves on the front panel in place of the present location on rear panel and remove J5 and J7.

(5) All mounting feet must be located in multiples of 2 inch centers.

(6) The timer subassembly must include a 21 megacycle oscillator produced by Monitor Products Company.

(7) An engineering fix must be included on the output probe of the RF assembly.

(8) All IF Amplifiers must be properly temperature compensated.

9. Model 520 Altimeter S/N 4 was installed in SATURN vehicle SA-4 and was flown as an experimental passenger on March 28, 1963. The Altimeter locked on to a side-lobe and tracked the return signal from an altitude of approximately 40 kilometers to 62 kilometers above the ocean surface. The Altimeter lost lock when the main engines were cut off and the booster was separated from the upper stage which apparently caused the booster to roll end over end. Telemetered test data indicated that the Altimeter operated properly throughout this portion of the

flight. Accuracy data indicates that the random error of the Altimeter is about ±30 meters which is within the Altimeter specifications. It is anticipated that the next perimental flight will offer a more favorable trajectory which will allow testing of the Altimeter performance to altitudes in excess of 200 kilometers.

D. CONCLUSIONS

Bench tests results (see Appendix) and the limited results of the flight tests show that the Model 520 Altimeter meets the specific operational requirements. Additional flight tests will be required to show that the Altimeter meets the specified altitude extremes. Further evaluations must be undertaken to determine if the Altimeter meets the vibration requirements. Evaluation of the Altimeter prove that the Model 520 design meets the accuracy and altitude requirements of space missions. From this starting point, many variations and modifications can be obtained to meet particular requirements.

II. RECOMMENDATIONS

The Model 520 Radar Altimeter program led to the development of the first high altitude altimeter to meet the requirements of orbiting vehicles. During the two year period a great deal of information was gained in the design and fabrication of this Altimeter. Experience has shown that additional tasks are required to provide further evaluation of the Altimeter and to provide altimeters that meet more exacting operational requirements. The following recommendations for action to improve the operation of the Altimeter are suggested:

A. Further tests should be performed to determine the validity of theoretical extrapolations of rather indefinite data on signal return. Tests to this date have not confirmed the theoretical expectation that the return pulse will have a rise time equal to the width of the transmitted pulse. These data along with more accurate information on reflectivity will aid in extending the accuracy and altitude of future altimeters.

B. The operational requirements of altimeters should be re-evaluated with the thought of providing altimeters as integral navigation instruments for orbiting vehicles. With the accuracies obtained by the Model 520, orbits of future vehicles could be maintained much more closely.

C. The following recommendations are suggested specifically for the Model 520 Altimeter:

1. Consider the possibility of redesigning the RF assembly to eliminate the RF frequency pulling encountered with load VSWR changes. Additional safety factor could be obtained by opening the duplexer frequency response. The possibility of increasing the power output from the RF assembly should be investigated to allow greater sensitivity.

2. The impedance match between the mixer output and the input of the RF Amplifier should be closely checked to obtain optimum signal transfer.

3. A mechanical redesign of the Model 520 should incorporate the latest packaging concepts innovated by MSFC and Ryan. The mechanical redesign should include a reduction in overall Altimeter size, lightening of the weight, integrating the RF assembly and provision for a solid frame construction with plug-in subassemblies for ease of maintenance.

4. Continued efforts should be made to increase the reliability and performance through the use of new components and techniques. To increase the performance of the Model 520 the following items should be considered:
   - (a) The use of floating grounds.
   - (b) Improve the 21 megacycle clock.
   - (c) Eliminate nuvisters in the Range Tracker.
   - (d) Replace relays with solid state devices in the Range Tracker.
   - (e) Improve power supply ripple and transient response.
   - (f) Provide decoupling in the Timer assembly.
   - (g) Regulate the 150 volt DC power source.
   - (h) Eliminate as many large size components as possible.

5. For future applications, differentiation of the altitude outputs should be considered to provide vertical velocity data.

PART III

APPENDIX

Some basic equations defining return signal waveforms are shown in the following.

Moore and Williams (Ref. 1, p. 233) have shown that the average return power as a function of time is given by

$$\overline{P_r}(d + 2h/c) = \int_0^d P_d(d - T)\, B(T)\, dT$$

in which d is delay time measured from the onset of the return pulse, h is the altitude c is the velocity of light, $P_d(t)$ is the transmitter power at time t, and B(T) is defined by

$$B(T) = \frac{c\lambda^2}{2(4\pi)^2\, r^3} \int_0^{2\pi} G^2(\theta, \phi)\, \sigma_o(\theta, \phi)\, d\phi \qquad T \geq 0$$

$$= 0 \qquad T < 0$$

In this expression, G and σ_o are the antenna gain and terrain cross section functions, respectively, λ is the wavelength, and r is range to the surface. The angles θ and ϕ are the angle from the vertical and the azimuth, respectively. The time variable, T, is defined by

$$T = 2(r - h)/c$$

Finally, it is noted that $r = h \sec \theta$.

Several simplifications can be made for the case presently of interest. First, no azimuth dependence is to be considered. Second, it is assumed that the antenna gain is constant over θ. Finally, the range of values of θ is restricted to small values such that $r \approx h$. Under these conditions, the function B(T) becomes

$$B(T) = \frac{G^2 \lambda^2 c}{64\pi^2 h^3} \sigma_o(\theta)$$

For small angles, T can be represented by

$$T = \frac{h}{c} \theta^2$$

from which

$$dT = \frac{2h}{c} \theta \, d\theta$$

Making the indicated substitutions, the return power function is

$$\overline{P_r} = \frac{G^2 \lambda^2}{32\pi^2 h^2} \int_0^{\theta_2} P_d(d - \frac{h}{c} \theta^2) \sigma_o(\theta) \theta \, d\theta$$

where θ_2 is $\sqrt{cd/h}$. It is assumed henceforth that the transmitted pulse is rectangular. Thus,

$$P_d(t) = \begin{cases} P_t & \cdots\cdots\cdots\cdots \quad 0 \leq t \leq \tau \\ 0 & \cdots\cdots\cdots\cdots \quad \text{elsewhere} \end{cases}$$

P_t is the peak power and τ is the pulse width. The expression for $\overline{P_r}$ is now

$$\overline{P_r} = \frac{P_t G^2 \lambda^2}{32\pi^2 h^2} \int_0^{\theta_2} \sigma_o(\theta) \theta \, d\theta \qquad d \leq \tau$$

A general expression for $\sigma_o(\theta)$ is

$$\sigma_o(\theta) = \sigma_o(0)\ e^{-\theta/\theta_1}$$

where $\sigma_o(\theta)$ is the cross section at vertical incidence and θ_1 is a constant depending on the terrain. This function has been suggested by some writers in the literature (e.g., Ref. 1).

Integrating for $\overline{P_r}$ gives

$$\overline{P_r} = \frac{\sigma_o(0)\ P_t\ G^2\ \lambda^2}{32\pi^2\ h^2}\quad \theta_1^{\,2}\ \left[1 - \exp\left(-\frac{1}{\theta_1}\sqrt{\frac{cd}{h}}\right)\left(1 + \frac{1}{\theta_1}\sqrt{\frac{cd}{h}}\right)\right]$$

which is valid for $0 \leq d \leq \tau$.

Two limiting cases are pointed out at this time to emphasize the generality of this expression for $\overline{P_r}$. First, as θ_1 becomes large, $\sigma_o(\theta)$ becomes constant for small angles and $\overline{P_r}$ approaches

$$\overline{P_r} = \frac{\sigma_o(0)\ P_t\ G^2\ \lambda^2\ cd}{64\pi^2\ h^3} \qquad 0 \leq d \leq \tau$$

which is the well-known formula for the return from an isotropic scattering terrain. On the other hand, as θ_1 becomes small, $\overline{P_r}$ approaches

$$\overline{P_r} = \frac{\sigma_o(0)\ P_t\ G^2\ \lambda^2}{32\pi^2\ h^2}\quad \theta_1^{\,2} \qquad 0 \leq d \leq \tau$$

which is the formula for specular return provided $\sigma_o(0)\ \theta_1^{\,2}$ is taken as the reflection coefficient.

Waveforms for intermediate values of θ_1 are now considered. Only the time-dependent portion of the expression for $\overline{P_r}$ need be considered. It is convenient to normalize this function by dividing by its value at $d = \tau$. Thus, the function P(d) is defined as

$$P(d) = \frac{1 - \exp\left(-\frac{1}{\theta_1}\sqrt{\frac{cd}{h}}\right)\left(1 + \frac{1}{\theta_1}\sqrt{\frac{cd}{h}}\right)}{1 - \exp\left(-\frac{1}{\theta_1}\sqrt{\frac{c\tau}{h}}\right)\left(1 + \frac{1}{\theta_1}\sqrt{\frac{c\tau}{h}}\right)}$$

from which the return power waveform is found by

$$\overline{P_r}(d + 2h/c) = A\,P(d)$$

where A is a constant (i. e., independent of time). The function P(d) is a normalized return power waveform.

The return power waveform is seen, according to this theory, to depend on the pulse width, the altitude, and the terrain directivity constant, θ_1.

<u>Observed Values of θ_1.</u> The angle θ_1 is that for which $\sigma_o(\theta)$ is down by a factor of e from σ_o at normal incidence. It is small for a smooth sea and tends to be larger for a rough sea. The experimental data of Reference 2 indicates that θ_1 is about 1.6 degrees for a Beaufort 1 sea.

<u>Waveforms.</u> Theoretical waveforms computed by the equation derived above, assuming a pulse width of one microsecond and θ_1 of 1.6 degrees, are given in Figure 16. It is seen that the rise time increases

markedly with altitude. For higher seas (larger values of θ_i) the curves tend toward those at the higher altitudes. The curves of Figure 16 represent average waveforms; i.e., the average of a large number of consecutive pulses. It may be expected that individual pulse waveforms may differ appreciably from the average.

The waveforms are altered, of course, by the response of the receiver. Thus, the tracker is in no case required to operate on a pulse with a rise time less than that of the receiver, which is about one-fourth microsecond.

Tracker Response. The response of the Model 520 Altimeter tracker can be inferred qualitatively from the curves of Figure 16. At lower altitudes the tracker will tend to track at a point earlier in time. At higher altitudes the tracking point will tend toward the point d = 0.5 microsecond. For higher sea states the tracking points tend to approach the 0.5 microsecond point more rapidly.

SUMMARY

A. PROGRAM SUMMARY

1. Contract NAS8-2459 covering the design, fabrication and delivery of altitude measuring equipment for use in the SATURN vehicle was signed between NASA (MSFC) and Ryan Electronics on 11 August 1961. The original contract called for three phases of work which are summarized below:

   a. Phase I: To commence at the contract date and to continue for a period of five months. During this period Ryan Electronics was required to design and construct an electrical breadboard model; develop a test program relative to electrical checkout, environmental testing and flight testing; design and document a complete prototype model and submit the documentation and test program to MSFC for approval.

   b. Phase II: To commence on approval of Phase I by the MSFC contracting officer. During the five months allocated for Phase II, Ryan Electronics was to fabricate one complete engineering prototype; test the engineering prototype to determine extent of compliance to the specification; submit test results for approval of the contracting officer; and upon approval of the engineering prototype, fabricate two production prototypes incorporating the final design. One of the production prototypes was to be tested to determine extent of compliance with the specification. Two full scale mock-ups were to be fabricated and delivered during this phase.

   c. Phase III: To commence after approval of items delivered in Phase II, and to continue for a period of four months. During this period Ryan Electronics was to fabricate two production Altimeters for use as space vehicle flight components. Also during this phase final documentation was to be submitted.

2. The Altimeter was divided into subassemblies for outside procurement during Phase I. Subcontractors were carefully surveyed and those selected were approved by the MSFC Contracting Officer. The Range Tracker subassembly and the case and chassis were designed by Ryan Electronics. Documentation required on Phase I of the program was delivered to the Technical Coordinator at MSFC on 11 January 1962. With this delivery Phase I of the program was completed on schedule.

3. Go-ahead on Phase II was received from the Contracting Officer on 11 January 1962. Based upon this go-ahead date and five months allowed for Phase II, Ryan was to complete this phase by 11 June 1962. The two mock-ups required during Phase II were delivered to MSFC in April 1962. The engineering prototype Altimeter was also completed at this time, but mechanical and electrical design problems caused delays of from three to four weeks.

4. Vibration and temperature tests of the engineering prototype Altimeter were completed in May of 1962. A report giving the results of the confidence tests was submitted to MSFC. Because of the delays in completing the confidence tests and making the necessary design changes in the engineering prototype, the contract schedule had slipped by approximately six to seven weeks. A meeting was held at MSFC between Ryan and MSFC technical and contracting personnel to discuss the best means of funding and scheduling the remainder of the program. As the result of these discussions, it was decided that the requirement for Ryan to environmentally test a production prototype and flight test the engineering prototype would be deleted. In addition, the requirement for two production units in the originally scheduled Phase III would be replaced by the production of four production prototypes. It was decided that environmental tests would be carried on at MSFC. During June of 1962, work was begun on the production of the four production prototype Altimeters. Also during this period MSFC planned to flight test portions of the

Altimeter and requested the use of the engineering prototype Altimeter for this purpose. The engineering prototype Altimeter was delivered to MSFC in June of 1962.

5. A meeting was held at MSFC between the Contracting Officer, Technical Coordinator and representatives of Ryan Electronics during the month of June 1962, to determine the best method of incorporating contract changes. The contract was then revised as follows:

   a. Phase II was extended to include the manufacture of four production prototypes, delivery to be made by 11 October 1962. Bench acceptance tests were to be run on each of these prototypes prior to shipment from Ryan. Environmental testing was to be accomplished at MSFC on the first production prototype.

   b. A new Phase III was to continue from the end of Phase II until 11 February 1963, however Phase III could not begin until go-ahead from MSFC. During this phase, five production Altimeters must be manufactured, acceptance tested and delivered by Ryan Electronics.

   c. Final documentation in the form of manufacturing drawings (as applicable), the final engineering report and the operation and instruction manual were to be delivered by 1 January 1963.

6. Production prototype Altimeter S/N 1 was completely assembled, acceptance tested and shipped to MSFC by 15 August 1962, where it was subjected to a bench test and environmental tests. Since this unit was scheduled to go directly into environmental tests, a Ryan engineer was also sent to MSFC to provide technical assistance. Two test sets were shipped to MSFC during this period for use in checking out the Altimeter. Bench tests on the first production Altimeter were successfully completed at MSFC during September 1962. However, the following troubles developed during the environmental tests on this Altimeter. The Timer subassembly, manufactured by Waugh Engineering Company developed an erratic count-down during high temperature. The trouble was traced to

the standardizer or pulse shaping circuit in the pulse count-down string. Also during tests at MSFC, the transmitter cavity developed an internal short. The mixer subassembly experienced two instances of fractured input signal ports. At low temperature the AGC circuit of the Tracker did not provide sufficient range of voltage to control the variation in gain of the LEL IF Amplifier. The Altimeter was shipped back to Ryan at the end of September 1962, for repair and design changes.

7. The month of October 1962, was expended in developing design changes required as a result of acceptance testing of Altimeter S/N 1 at MSFC. The changes that were made include temperature compensation in the standardizer circuit of the Timer subassembly and changes to the electrical connectors of the crystal diodes in the mixer subassembly. In addition, changes were made to the AGC circuit of the Tracker subassembly and the gain-AGC curve of the IF Amplifier was shifted to coincide with the curve as measured in the engineering prototype IF Amplifier. All modifications were incorporated in Altimeter S/N 2 which was bench acceptance tests at Ryan and shipped to MSFC on 26 October 1962. After successfully passing the bench acceptance test, Altimeter S/N 2 suffered an unexplainable varactor diode failure. With replacement of the varactor diode and the crystal mixer diode Altimeter S/N 2 continued to operate properly in the SATURN vehicle for several weeks. After extensive use the Altimeter became noisy and was unable to track time delays below 300 microseconds. Because of this problem Altimeter S/N 2 was returned to Ryan for repair.

8. The design changes were incorporated in Altimeter S/N 1 and the unit was given confidence, temperature, and limited vibration tests, as well as bench acceptance test. The unit passed all these tests and was shipped to MSFC on 5 November 1962. The unit was checked on the bench and met all the requirements of the specification. The unit operated properly during 75°C temperature tests. Again

at -20°C the variation in gain of the IF Amplifier was too great to be compensated by the AGC voltage, which resulted in marginal operation. The Altimeter was then subjected to a 5 G noise vibration test. During this test the Altimeter lost lock intermittently. It was also noted that the Tracker gate remained fixed in one position intermittently. The unit was rejected to Ryan for repair and possible redesign.

9. On 15 December 1962 partial acceptance testing of S/N 3 Altimeter was accomplished. The Altimeter was installed in the temperature chamber on 16 December but a failure occurred in the 21 megacycle crystal oscillator. The crystal oscillator was replaced with the oscillator in S/N 2. During the evening of 17 December the temperature chamber failed to operate properly, therefore temperature tests were inconclusive. Also during this time the crystal diodes in the mixer subassembly failed. On 18 December further tests were made and another pair of crystal mixer diodes failed. At this time the local oscillator failed at low temperature and the second 21 megacyle crystal oscillator failed due to an internal short. This failure left only one 21 megacycle oscillator which had been used in the Altimeter S/N 1. The Technical Coordinator was called on 18 December to obtain permission to use the 21 megacycle oscillator from Altimeter S/N 1. He gave permission and tests continued. However, because of the deterioration of the mixer diodes, it was decided to change the RF assembly. This was accomplished and complete acceptance test was run on S/N 3. The Altimeter worked satisfactorily with a sensitivity of -89 DBM and passed all bench tests. However, after mounting it in the case and applying power (after a three minute warm-up) the sensitivity had again deteriorated. The unit was again taken out of the case and the mixer diodes replaced and the unit subjected to one more test. It passed the test successfully and was hand carried to MSFC on 18 December. Upon receipt at MSFC, the unit was successfully acceptance tested by the Technical Coordinator and the Ryan representative.

10. Altimeter S/N 4 was installed in SATURN vehicle SA-4 and was successfully flown in March 1963. Also during March 1963, the manufacture of five follow-on Altimeters was initiated by MSFC. Altimeter S/N 5 was delivered in June 1963 and Altimeter S/N 6 in July 1963 and Altimeter S/N 7 in August 1963. Altimeters S/N 8 and 9 are being delivered in September concurrent with this report.

B. DESCRIPTION OF MODEL 520 RADAR ALTIMETER

The Ryan Model 520 Radar Altimeter is a high altitude, pulse altimeter intended for use in spacecrafts to altitudes as great as 250 statute miles, or 400 kilometers. The Model 520 is especially well suited to its purpose because of its small size, light weight, high reliability, low power consumption and rigorous environmental specifications. The high accuracy (±32 meters) and fast response of the Model 520 makes it a valuable instrument for a variety of purposes including orbit determination and guidance.

The Radar Altimeter was developed on a NASA (MSFC) contract to serve as part of the instrumentation of SATURN vehicles.

The Model 520 Altimeter measures terrain clearance by sensing the two way propogation time of narrow microwave pulses between the spacecraft and the surface of the earth. The Model 520 equipment is designed for use with a wide beam antenna to provide broad tolerances in pitch and roll within antenna stabilization. The accuracy of the Altimeter is not degraded by moderate attitude changes, nor by high horizontal velocities.

The equipment weighs only 25.9 pounds and consumes only 65 watts of primary power, at 28 volts DC. The altitude output is an 18 bit parallel binary word updated 36 times per second. A nine bit precision time output with a resolution of 0.5 second is also provided. Signal loss or malfunction is monitored by means of a signal loss indicator. The only external control required is switching for "on" or "standby" operation.

The design of the Model 520 Altimeter is such that it can be adapted to a wide range of different requirements with relatively simple modifications. Depending on the specific requirements a potential for reduced weight, greater altitude capability and greater reliability exists.

RYAN ELECTRONICS
REPORT NO. 52065-1B

Test *ACCEPTANCE*

Eqpt. *MODEL 520*

Serial No. *9*

Date *9-12-63*

Test Engr. *[illegible signature]*

Witness *[illegible signature]*

Par.	Test	Reqmnt.	Measured
3.1	Trans. Freq.	1610 ±5 MC	*1611.25*
3.2 (4) (e)	High Freq.	As Measured	*1612.75*
(d)	Low Freq.	As Measured	*1610.0*
(5) (b)	Bandpass	3.0 ±1.0 MC	*2.75*
(e)	Center Freq.	Equal to 3.1 within 0.5 MC	*1611.38*
3.3 (3) (f)	Noise Ind.	As Measured	*12*
(g)	Cable Loss	As Measured	*.78*
(h)	Noise Figure	Shall not exceed 8.0 db	*11.22**
3.4	PRF	14400 ±2 counts	*14400*
3.5	Pulse Width	From 0.8 to 1.1 µs.	*0.89*
	Rise Time	Less than 0.1 µs. (10% to 90%)	*0.075*
	Decay Time	Less than 0.5 µs. (90% to 10%)	*0.2*
3.6	Trans. Power	5 KW Min.	*6.5*
3.7	Clock Freq.	212.33664×10^6 ±212 counts	*212.33654×10^6*
	Clock Freq.	100 ±2 counts	*100*
3.8	Vert. Velocity	Ascending at 50 to 175 KM 175 to 400 KM	 *OK* *OK*
		Descending at 400 to 175 KM 175 to 50 KM	 *OK* *OK*
3.9	Overall System Accuracy	2411.63 ±0.2034 µs. 1459.18 ±0.2034 µs. 386.17 ±0.2034 µs.	*2411.6* *[illegible]* *386.1*
3.10	Inhibit Signal	5 ±0.5 VDC 0 ±0.5 VDC	*4.5* *0.2*

**Acceptable if bandpass within spec and sensitivity is better than -86 dbm.*
OK [illegible signature]

Data Sheet
Sheet 1 of 3

[illegible]
[illegible]

Par.		Test	Reqmnt.
3.10	(b)	Elapsed Time Word	5 ±0.5VDC Indicator ON 0 ±0.5 VDC Indicators OFF

Measured

IND.	ON	OFF
2^0	4.6	0.05
2^1	"	0.1
2^2	"	"
2^3	"	"
2^4	"	"
2^5	"	"
2^6	"	"
2^7	"	"
2^8	4.5	"

Par.		Test	Reqmnt.
	(c)	Altitude Word	5 ±0.5 VDC Indicator ON 0 ±0.5 VDC Indicator OFF

IND.	ON	OFF
2^0	5.2	0.05
2^1	"	"
2^2	"	"
2^3	"	"
2^4	"	"
2^5	"	"
2^6	"	"
2^7	5.1	0.05
2^8	5.1	0.05
2^9	5.1	0.05
2^{10}	5.1	0.05
2^{11}	5.0	0.05
2^{12}	5.1	0.05
2^{13}	5.1	0.05
2^{14}	5.0	0.05
2^{15}	5.1	0.05
2^{16}	5.2	0.05
2^{17}	5.1	0.05

NOTE: Indicators 2^0 through 2^4 may jitter too much for an accurate voltage measurement. For these check that the voltage is present or absent.

Data Sheet
Sheet 2 of 3

K. D. Ellington
Wayne Smith

Par.	Test	Reqmnt.	Measured
3.10	(d.) Power Supply	1.25 ±0.25 VDC	1.359
		No Ground Effect	NO
	(e) Filter Output	Varying Voltage	
		from 0.5 to 5.0 VDC	0.217 → +4.159
		No Ground Effect	NO
	(f) AGC	Approx. -0.6 to 0.0 VDC	-.059 → -.188
		No Ground Effect	NO
	(g) Reliability	Track 4.5 ±0.5 VDC	+4.769
		Search 0 ±0.2 VDC	+0.129
		No Ground Effect	NO
	(h) Transmit Sig.	H.V. ON -0.1 ±0.02 VDC	-0.113
		H.V. OFF 0 ±0.02 VDC	.002
		No Ground Effect	NO
3.11	Power Consumption	Oven OFF-less than 65 W.	62w
		Oven ON-less than 80 W.	65w

Data Sheet
Sheet 3 of 3

RYAN ELECTRONICS
REPORT NO. 52065-1B

Test ACCEPTANCE — Date 9/9/63

Eqpt. MODEL 520 — Test Engr. R.D. ELLERTSON

Serial No. 8 — Witness C H Hem

Par.	Test	Reqmnt.	Measured
3.1	Trans. Freq.	1610 ±5 MC	~~1612~~.6
3.2 (4) (e)	High Freq.	As Measured	1613
(d)	Low Freq.	As Measured	1610
(5) (b)	Bandpass	3.0 ±1.0 MC	3.0
(e)	Center Freq.	Equal to 3.1 within 0.5 MC	1611.5
3.3 (3) (f)	Noise Ind.	As Measured	8.5
(g)	Cable Loss	As Measured	.72
(h)	Noise Figure	Shall not exceed 8.0 db	7.78
3.4	PRF	14400 ±2 counts	14400
3.5	Pulse Width	From 0.8 to 1.1 μs.	.88
	Rise Time	Less than 0.1 μs. (10% to 90%)	.058
	Decay Time	Less than 0.5 μs. (90% to 10%)	.2
3.6	Trans. Power	5 KW Min.	7.5 KW
3.7	Clock Freq.	212.33664×10^6 ±212 counts	21233668
	Clock Freq.	100 ±2 counts	100
3.8	Vert. Velocity	Ascending at 50 to 175 KM 175 to 400 KM	 OK OK
		Descending at 400 to 175 KM 175 to 50 KM	 OK OK
3.9	Overall System Accuracy	2411.63 ±0.2034 μs. 1459.18 ±0.2034 μs. 386.17 ±0.2034 μs.	2411.65 1459.2 386.2
3.10	Inhibit Signal	5 ±0.5 VDC 0 ±0.5 VDC	4.8 0.18

Data Sheet
Sheet 1 of 3

S/N 8

CH Hen
J.T. [illegible]

Par.		Test	Reqmnt.
3.10	(b)	Elapsed Time Word	5 ±0.5VDC Indicator ON 0 ±0.5 VDC Indicators OFF

Measured

IND.	ON	OFF
2^0	4.6	0.1
2^1	4.8	0.18
2^2	"	"
2^3	"	"
2^4	"	"
2^5	"	"
2^6	"	"
2^7	"	"
2^8	4.6	"

Par.		Test	Reqmnt.
	(c)	Altitude Word	5 ±0.5 VDC Indicator ON 0 ±0.5 VDC Indicator OFF

IND.	ON	OFF
2^0	5.2	0.05
2^1	5.3	"
2^2	"	"
2^3	"	"
2^4	"	"
2^5	"	"
2^6	"	"
2^7	"	"
2^8	"	"
2^9	"	"
2^{10}	"	"
2^{11}	"	"
2^{12}	"	"
2^{13}	"	"
2^{14}	"	"
2^{15}	"	"
2^{16}	"	"
2^{17}	"	"

NOTE: Indicators 2^0 through 2^4 may jitter too much for an accurate voltage measurement. For these check that the voltage is present or absent.

Data Sheet.
Sheet 2 of 3

S/N 8

C Allen
R. [illegible]

Par.	Test	Reqmnt.	Measured
3.10	(d) Power Supply	1.25 ±0.25 VDC	+1.27
		No Ground Effect	OK
	(e) Filter Output	Varying Voltage from 0.5 to 5.0 VDC	0.2 to 4.5
		No Ground Effect	OK
	(f) AGC	Approx. -0.6 to 0.0 VDC	-0.34 to 0.06
		No Ground Effect	OK
	(g) Reliability	Track 4.5 ±0.5 VDC	4.7
		Search 0 ±0.2 VDC	+0.14
		No Ground Effect	OK.
	(h) Transmit Sig.	H.V. ON -0.1 ±0.02 VDC	-0.119
		H.V. OFF 0 ±0.02 VDC	0.011
		No Ground Effect	OK.
3.11	Power Consumption	Oven OFF-less than 65 W.	62 W
		Oven ON-less than 80 W.	65 W

Data Sheet
Sheet 3 of 3

RYAN ELECTRONICS

REPORT NO. 52065-1B

Test *ACCEPTANCE*　　　　　　　　Date *8/12/63*

Eqpt. *MODEL 520*　　　　　　　　Test Engr. [signature]

Serial No. *7*　　　　　　　　　　Witness [signature]

Par.	Test	Reqmnt.	Measured
3.1	Trans. Freq.	1610 ±5 MC	1607.2
3.2 (4) (e)	High Freq.	As Measured	1608.9
(d)	Low Freq.	As Measured	1606.2
(5) (b)	Bandpass	3.0 ±1.0 MC	2.7
(e)	Center Freq.	Equal to 3.1 within 0.5 MC	1607.5
3.3 (3) (f)	Noise Ind.	As Measured	10.0
(g)	Cable Loss	As Measured	0.8
(h)	Noise Figure	Shall not exceed 8.0 db	9.2
3.4	PRF	14400 ±2 counts	14400
3.5	Pulse Width	From 0.8 to 1.1 μs.	.85
	Rise Time	Less than 0.1 μs. (10% to 90%)	.095
	Decay Time	Less than 0.5 μs. (90% to 10%)	.25
3.6	Trans. Power	5 KW Min.	7.1
3.7	Clock Freq.	212.33664×10^6 ±212 counts	212.336579
	Clock Freq.	100 ±2 counts	100
3.8	Vert. Velocity	Ascending at 50 to 175 KM 175 to 400 KM	 OK OK
		Descending at 400 to 175 KM 175 to 50 KM	 OK OK
3.9	Overall System Accuracy	2411.63 ±0.2034 μs. 1459.18 ±0.2034 μs. 386.17 ±0.2034 μs.	2411.65 1459.2 386.17
3.10	Inhibit Signal	5 ±0.5 VDC 0 ±0.5 VDC	4.5 0.1

Data Sheet
Sheet 1 of 3

S/N 7

RYAN ELECTRONICS

REPORT NO. 52065-1B

Par.		Test	Reqmnt.
3.10	(b)	Elapsed Time Word	5 ±0.5VDC Indicator ON; 0 ±0.5 VDC Indicators OFF

Measured

IND.	ON	OFF
2^0	4.6	0.15
2^1	4.7	"
2^2	"	0.1
2^3	"	"
2^4	"	"
2^5	"	"
2^6	"	"
2^7	"	"
2^8	"	0.15

		Test	Reqmnt.
	(c)	Altitude Word	5 ±0.5 VDC Indicator ON; 0 ±0.5 VDC Indicator OFF

IND.	ON	OFF
2^0	5.05	0.05
2^1	"	0.1
2^2	"	"
2^3	"	"
2^4	"	"
2^5	"	"
2^6	"	"
2^7	"	"
2^8	"	"
2^9	"	"
2^{10}	"	"
2^{11}	"	"
2^{12}	"	"
2^{13}	5.1	0.05
2^{14}	5.05	0.1
2^{15}	5.05	0.1
2^{16}	5.1	.05
2^{17}	5.1	0.1

NOTE: Indicators 2^0 through 2^4 may jitter too much for an accurate voltage measurement. For these check that the voltage is present or absent.

Data Sheet
Sheet 2 of 3

S/N 7

CAH

RYAN ELECTRONICS
REPORT NO. 52065-1B

Par.	Test	Reqmnt.	Measured
3.10	(d) Power Supply	1.25 ±0.25 VDC	1.37
		No Ground Effect	OK
	(e) Filter Output	Varying Voltage from 0.5 to 5.0 VDC	0.21 to 4.4
		No Ground Effect	OK
	(f) AGC	Approx -0.6 to 0.0 VDC	-.32 to .06
		No Ground Effect	OK
	(g) Reliability	Track 4.5 ±0.5 VDC	4.87
		Search 0 ±0.2 VDC	0.1
		No Ground Effect	OK
	(h) Transmit Sig.	H.V. ON -0.1 ±0.02 VDC	-0.1
		H.V. OFF 0 ±0.02 VDC	0.001
		No Ground Effect	OK
3.11	Power Consumption	Oven OFF-less than 65 W.	64
		Oven ON-less than 80 W.	67.5

Data Sheet
Sheet 3 of 3

RYAN ELECTRONICS

REPORT NO. 52065-1B

Test: *Acceptance*

Eqpt.: *Model 520 Altimeter*

Serial No.: *6*

Date: *27 June 1963*

Test Engr.:

Witness: [illegible]

Par.	Test	Reqmnt.	Measured
3.1	Trans. Freq.	1610 ±5 MC	1612
3.2 (4) (e)	High Freq.	As Measured	1613
(d)	Low Freq.	As Measured	1611
(5) (b)	Bandpass	3.0 ±1.0 MC	2.0
(e)	Center Freq.	Equal to 3.1 within 0.5 MC	1612
3.3 (3) (f)	Noise Ind.	As Measured	10.5
(g)	Cable Loss	As Measured	0.7
(h)	Noise Figure	Shall not exceed 8.0 db	9.2 *
3.4	PRF	14400 ±2 counts	14400
3.5	Pulse Width	From 0.8 to 1.1 µs.	0.84
	Rise Time	Less than 0.1 µs. (10% to 90%)	0.078
	Decay Time	Less than 0.5 µs. (90% to 10%)	0.28
3.6	Trans. Power	5 KW Min.	8.0 KW
3.7	Clock Freq.	212.33664×10^6 ±212 counts	21233670.7
	Clock Freq.	100 ±2 counts	100
3.8	Vert. Velocity	Ascending at	
		50 to 175 KM	OK
		175 to 400 KM	OK
		Descending at	
		400 to 175 KM	OK
		175 to 50 KM	OK
3.9	Overall System Accuracy	2411.63 ±0.2034 µs.	2411.7
		1459.18 ±0.2034 µs.	1459.2
		386.17 ±0.2034 µs.	386.2
3.10	Inhibit Signal	5 ±0.5 VDC	4.8
		0 ±0.5 VDC	0.2

Data Sheet
Sheet 1 of 3

Par.		Test	Reqmnt.
3.10	(b)	Elapsed Time Word	5 ±0.5VDC Indicator ON; 0 ±0.5 VDC Indicators OFF

Measured

IND.	ON	OFF
2^0	4.6	0.05
2^1	"	0.1
2^2	"	"
2^3	"	"
2^4	"	"
2^5	"	"
2^6	"	"
2^7	"	"
2^8	4.5	"

Par.		Test	Reqmnt.
	(c)	Altitude Word	5 ±0.5 VDC Indicator ON; 0 ±0.5 VDC Indicator OFF

IND.	ON	OFF
2^0	5.2	0.05
2^1	"	"
2^2	"	"
2^3	"	"
2^4	"	"
2^5	"	"
2^6	"	"
2^7	5.1	0.05
2^8	5.1	0.05
2^9	5.1	0.05
2^{10}	5.1	0.05
2^{11}	5.0	0.05
2^{12}	5.1	0.05
2^{13}	5.1	0.05
2^{14}	5.0	0.05
2^{15}	5.1	0.05
2^{16}	5.2	0.05
2^{17}	5.1	0.05

NOTE: Indicators 2^0 through 2^4 may jitter too much for an accurate voltage measurement. For these check that the voltage is present or absent.

Data Sheet
Sheet 2 of 3

S/N 6

Par.		Test	Reqmnt.
3.10	(b)	Elapsed Time Word	5 ±0.5VDC Indicator ON 0 ±0.5 VDC Indicators OFF

Measured

IND.	ON	OFF
2^0	4.6	0.10
2^1	4.6	0.15
2^2	4.6	0.15
2^3	4.6	0.15
2^4	4.6	0.20
2^5	4.6	0.25
2^6	4.6	0.25
2^7	4.6	0.25
2^8	4.6	[illegible]

Par.		Test	Reqmnt.
	(c)	Altitude Word	5 ±0.5 VDC Indicator ON 0 ±0.5 VDC Indicator OFF

IND.	ON	OFF
2^0	5.1	0.1
2^1	5.1	0.1
2^2	5.25	0.1
2^3	5.1	0.1
2^4	5.1	0.1
2^5	5.15	0.1
2^6	5.1	0.1
2^7	5.1	0.1
2^8	5.15	0.1
2^9	5.1	0.1
2^{10}	5.1	0.1
2^{11}	5.1	0.1
2^{12}	5.1	0.1
2^{13}	5.1	[illegible]
2^{14}	5.15	[illegible]
2^{15}	5.15	[illegible]
2^{16}	5.1	0.2
2^{17}	5.2	0.1

NOTE: Indicators 2^0 through 2^4 may jitter too much for an accurate voltage measurement. For these check that the voltage is present or absent.

Data Sheet
Sheet 2 of 3

Hjeklema
CHHen

RYAN ELECTRONICS
REPORT NO. 52065-1B

S/N 6

Par.	Test	Reqmnt.	Measured
3.10	(d) Power Supply	1.25 ±0.25 VDC	1.299
		No Ground Effect	OK
	(e) Filter Output	Varying Voltage	
		from 0.5 to 5.0 VDC	0.22 TO +4.306
		No Ground Effect	OK
	(f) AGC	Approx. -0.6 to 0.0 VDC	-.3495-.059
		No Ground Effect	OK
	(g) Reliability	Track 4.5 ±0.5 VDC	+4.687
		Search 0 ±0.2 VDC	+0.140
		No Ground Effect	OK
	(h) Transmit Sig.	H.V. ON -0.1 ±0.02 VDC	-0.089
		H.V. OFF 0 ±0.02 VDC	-0.009
		No Ground Effect	OK
3.11	Power Consumption	Oven OFF-less than 65 W.	61.5
		Oven ON-less than 80 W.	72.5

Data Sheet
Sheet 3 of 3

RYAN ELECTRONICS

REPORT NO. 52065-1B

Test *Acceptance* Date *6/3/63*

Eqpt. *Model 580* Test Engr. ______

Serial No. *5* Witness [illegible]

Par.	Test	Reqmnt.	Measured
3.1	Trans. Freq.	1610 ±5 MC	1613
3.2 (4) (e)	High Freq.	As Measured	[illegible]
(d)	Low Freq.	As Measured	1612
(5) (b)	Bandpass	3.0 ±1.0 MC	2.0
(e)	Center Freq.	Equal to 3.1 within 0.5 MC	1613
3.3 (3) (f)	Noise Ind.	As Measured	13.7
(g)	Cable Loss	As Measured	0.7
(h)	Noise Figure	Shall not exceed 8.0 db	13.0 *
3.4	PRF	14400 ±2 counts	14400
3.5	Pulse Width	From 0.8 to 1.1 µs.	0.82
	Rise Time	Less than 0.1 µs. (10% to 90%)	0.10
	Decay Time	Less than 0.5 µs. (90% to 10%)	0.45
3.6	Trans. Power	5 KW Min.	7.5 KW
3.7	Clock Freq.	212.33664×10^6 ±212 counts	212.3365
	Clock Freq.	100 ±2 counts	100
3.8	Vert. Velocity	Ascending at	
		50 to 175 KM	OK
		175 to 400 KM	OK
		Descending at	
		400 to 175 KM	OK
		175 to 50 KM	OK
3.9	Overall System Accuracy	2411.63 ±0.2034 µs.	2411.6
		1459.18 ±0.2034 µs.	[illegible]
		386.17 ±0.2034 µs.	386.1
3.10	Inhibit Signal	5 ±0.5 VDC	4.5
		0 ±0.5 VDC	0.2

* ACCEPTABLE BY MFSC (W. CASE) PER TEL CON WITH M. OLTHOFF 6/19/63

Data Sheet
Sheet 1 of 3

5/15

Par.		Test	Reqmnt.
3.10	(b)	Elapsed Time Word	5 ±0.5VDC Indicator ON 0 ±0.5 VDC Indicators OFF

Measured

IND.	ON	OFF
2^0	4.8	0.15
2^1	4.8	0.2
2^2	4.8	0.2
2^3	4.7	0.2
2^4	4.75	0.15
2^5	4.75	0.15
2^6	4.7	0.2
2^7	4.75	0.1
2^8	4.75	0.15

Par.		Test	Reqmnt.
	(c)	Altitude Word	5 ±0.5 VDC Indicator ON 0 ±0.5 VDC Indicator OFF

IND.	ON	OFF
2^0	5.35	0.1
2^1	5.35	0.1
2^2	5.3	0.05
2^3	5.3	0.05
2^4	5.3	0.05
2^5	5.3	0.05
2^6	5.2	0.05
2^7	5.2	0.05
2^8	5.1	0.05
2^9	5.2	0.05
2^{10}	5.3	0.10
2^{11}	5.25	0.10
2^{12}	5.3	0.10
2^{13}	5.2	0.10
2^{14}	5.2	0.05
2^{15}	5.2	0.05
2^{16}	5.2	0.05
2^{17}	5.2	0.10

NOTE: Indicators 2^0 through 2^4 may jitter too much for an accurate voltage measurement. For these check that the voltage is present or absent.

Data Sheet.
Sheet 2 of 3

RYAN ELECTRONICS
REPORT NO. 52065-1B

S/N 5

Par.	Test	Reqmnt.	Measured
3.10	(d) Power Supply	1.25 ±0.25 VDC	1.317
		No Ground Effect	OK
	(e) Filter Output	Varying Voltage	
		from 0.5 to 5.0 VDC	.5 to 4.666
		No Ground Effect	OK
	(f) AGC	Approx. -0.6 to 0.0 VDC	-0.57 to -.288
		No Ground Effect	OK
	(g) Reliability	Track 4.5 ±0.5 VDC	+4.569
		Search 0 ±0.2 VDC	+0.167
		No Ground Effect	OK
	(h) Transmit Sig.	H.V. ON -0.1 ±0.02 VDC	-0.087
		H.V. OFF 0 ±0.02 VDC	-0-
		No Ground Effect	OK
3.11	Power Consumption	Oven OFF-less than 65 W.	63.5
		Oven ON-less than 80 W.	78.5

Data Sheet
Sheet 3 of 3

5/NY

RYAN ELECTRONICS

REPORT NO. 52065-2A

Test Performance
Eqpt. Model 520 Radar Altimeter
Serial No. 4
Primary Power 28 VDC ~~26 VDC~~ ~~29.5 VDC~~ (Delete two)
Ref. Para. 4.2

Date 2/16/63
Test Engr. [illegible]
Witness [illegible]

Para.	Test	Reqmnt.	Measured
3.1	Trans. Freq.	1610 ± 5 MC	1612.25
3.2 (4) (e)	High Freq.	As Measured	1613.5
(d)	Low Freq.	As Measured	1610.25
(5) (b)	Bandpass	3.0 ± 0.5 MC	3.25
(e)	Center Freq.	Equal to 3.1 within 0.5 MC	1611.875
3.3 (3) (a)	Noise Ind.	0.2 to 0.4 VP/P	—
(d) 1.	Noise Insertion	As Measured (DB)	—
2.	Correction	(1.75 DB at 1.610 KMC)	—
3.	Cable Loss	As Calibrated	—
5.	Noise Factor	Shall not exceed 8.0 DB	8.8 db
3.4	PRF	14400 ± 2 counts	14400
3.5	Pulse Width	From 0.8 to 1.1 us.	0.82
	Rise Time	Less than 0.1 us. (10% to 90%)	0.09
	Decay Time	Less than 0.5 us. (90% to 10%)	0.18
3.6	Trans. Power	5 KW Min.	6.5 KW
3.7	Clock Freq. (20 MC)	212.33664×10^6 ± 212 counts	21233676
	Clock Freq. (2 CPS)	100 ± 2 counts	100
3.8	Vert. Velocity Tracking at 6KM/sec.	Ascending at	
		50 to 175 KM	OK
		175 to 400 KM	OK
		Descending at	
		400 to 175 KM	OK
		175 to 50 KM	OK
3.9	Overall System Accuracy	2411.63 ± 0.2034 us.	2411.70
		1459.18 ± 0.2034 us.	1459.05
		386.17 ± 0.2034 us.	386.1
3.10 (a)	Inhibit Signal	5 ± 0.5 VDC	4.6
		0 ± 0.5 VDC	0.2

Data Sheet 1
Sheet 1 of 3

NOTE: Reproduce three copies for tests.

S/N 4

Witness - [illegible]

RYAN ELECTRONICS
REPORT NO. 52065-2A

Primary Power 28 VDC ~~26 VDC~~ ~~29.5 VDC~~ (Delete Two)

Para.	Test	Reqmnt.
3.10	(b) Elapsed Time Word	5 ± 0.5 VDC Indicator ON; 0 ± 0.5 VDC Indicator OFF

Measured

IND.	ON	OFF
2^0	4.6	0.15
2^1	4.6	0.15
2^2	4.6	0.15
2^3	4.6	0.15
2^4	4.6	0.15
2^5	4.6	0.15
2^6	4.6	0.20
2^7	4.6	0.20
2^8	4.6	0.20

Para.	Test	Reqmnt.
	(c) Altitude Word	5 ± 0.5 VDC Indicator ON; 0 ± 0.5 VDC Indicator OFF

IND.	ON	OFF
2^0	5.2	0.04
2^1	5.1	0.04
2^2	5.1	0.04
2^3	5.1	0.04
2^4	5.1	0.04
2^5	5.15	0.10
2^6	5.1	0.10
2^7	5.1	0.10
2^8	5.2	0.10
2^9	5.2	0.10
2^{10}	5.1	0.10
2^{11}	5.2	0.10
2^{12}	5.1	0.20
2^{13}	5.1	0.10
2^{14}	5.1	0.20
2^{15}	5.1	0.20
2^{16}	5.1	0.10
2^{17}	5.1	0.10

NOTE: Indicators 2^0 through 2^4 may jitter too much for an accurate voltage measurement. For these check that the voltage is present or absent.

NOTE: Reproduce three copies for tests.

Data Sheet 1
Sheet 2 of 3

SMF —Witnessed by C. Hilbery

RYAN ELECTRONICS
REPORT NO. 52065-2A

Primary Power 28 VDC ~~26 VDC~~ ~~29.5 VDC~~ (Delete Two) 28V 29.5V 26V

Para.	Test	Reqmnt.	Measured		
3.10	* (d) Power Supply	1.5 MAX ~~2.5 VDC~~	1.384	1.464	1.28
	(e) Filter Output	Varying Voltage			
		from 0.5 to 5.0 VDC	0.24 to 4.00		
		No Ground Effect	OK		
	(f) AGC	-0.6 to 0.0 VDC	-0.064 to -0.434		
		No Ground Effect	OK		
	* (g) Reliability	Track 4.5 ~~5~~ ± 0.5 ~~0.2~~ VDC	4.6		
		No Ground Effect	OK		
	* (h) Transmit Sig.	H.V. ON -.112 MAX ~~-0.1 ± 0.05~~ VDC	-0.088		
		H.V. OFF 0 ± 0.02 VDC	-0.006		
		No Ground Effect	OK		
3.11	Power Consumption	Oven OFF-less than 65 W.	61.6		
		Oven ON-less than 80 W.	75.6		

* Limits changed by NASA request.
M. L. [illegible]

Data Sheet 1
Sheet 3 of 3

NOTE: Reproduce three copies for tests.

RYAN ELECTRONICS

REPORT NO. 52065-2A

Test Performance
Eqpt. Model 520 Radar Altimeter
Serial No. 3
Primary Power 28 VDC ~~26 VDC~~ ~~29.5 VDC~~ (Delete two)
Ref. Para. 4.2

Date ?/ /
Test Engr.
Witness

Para.	Test	Reqmnt.	Measured
3.1	Trans. Freq.	1610 ± 5 MC	1609.25
3.2 (4) (c)	High Freq.	As Measured	1611.0
(d)	Low Freq.	As Measured	1607.5
(5) (b)	Bandpass	3.0 ± 0.5 MC	3.5
(e)	Center Freq.	Equal to 3.1 within 0.5 MC	1609.25
3.3 (3) (a)	Noise Ind.	0.2 to 0.4 VP/P	— NA
(d) 1.	Noise Insertion	As Measured (DB)	— NA
2.	Correction	(1.75 DB at 1.610 KMC)	— NA
3.	Cable Loss	As Calibrated	— NA
5.	Noise Factor	Shall not exceed 8.0 DB	7.3 db
3.4	PRF	14400 ± 2 counts	14400
3.5	Pulse Width	From 0.8 to 1.1 us.	0.82 µs
	Rise Time	Less than 0.1 us. (10% to 90%)	0.10 µs
	Decay Time	Less than 0.5 us. (90% to 10%)	0.18 µs
3.6	Trans. Power	5 KW Min.	6.2 KW
3.7	Clock Freq. (20 MC)	212.33664×10^6 ± 212 counts	21233166
	Clock Freq. (2 CPS)	100 ± 2 counts	100
3.8	Vert. Velocity Tracking at 6KM/sec.	Ascending at	
		50 to 175 KM	OK
		175 to 400 KM	OK
		Descending at	
		400 to 175 KM	OK
		175 to 50 KM	OK
3.9	Overall System Accuracy	2411.63 ± 0.2034 us.	2411.7
		1459.18 ± 0.2034 us.	1459.2
		386.17 ± 0.2034 us.	386.1
3.10 (a)	Inhibit Signal	5 ± 0.5 VDC	4.6
		0 ± 0.5 VDC	0.2

Data Sheet 1
Sheet 1 of 3

NOTE: Reproduce three copies for tests.

CAHenry

RYAN ELECTRONICS

REPORT NO. 52065-2A

S/N 3

Primary Power ~~28 VDC~~ ~~26 VDC~~ 29.5 VDC (Delete Two)

Para.		Test	Reqmnt.
3.10	(b)	Elapsed Time Word	5 ± 0.5 VDC Indicator ON 0 ± 0.5 VDC Indicator OFF

Measured

IND.	ON	OFF
2^0	[illegible]	[illegible]
2^1	[illegible]	[illegible]
2^2	[illegible]	[illegible]
2^3	[illegible]	[illegible]
2^4	[illegible]	[illegible]
2^5	[illegible]	[illegible]
2^6	[illegible]	[illegible]
2^7	[illegible]	[illegible]
2^8	[illegible]	.2

(c)	Altitude Word	5 ± 0.5 VDC Indicator ON 0 ± 0.5 VDC Indicator OFF

IND.	ON	OFF
2^0	[illegible]	[illegible]
2^1	[illegible]	[illegible]
2^2	[illegible]	[illegible]
2^3	[illegible]	[illegible]
2^4	[illegible]	[illegible]
2^5	5.1	[illegible]
2^6	[illegible]	[illegible]
2^7	[illegible]	[illegible]
2^8	[illegible]	[illegible]
2^9	5.1	[illegible]
2^{10}	[illegible]	[illegible]
2^{11}	5.15	[illegible]
2^{12}	[illegible]	[illegible]
2^{13}	5.1	0.05
2^{14}	[illegible]	[illegible]
2^{15}	[illegible]	[illegible]
2^{16}	5.1	0.05
2^{17}	5.1	[illegible]

NOTE: Indicators 2^0 through 2^4 may jitter too much for an accurate voltage measurement. For these check that the voltage is present or absent.

NOTE: Reproduce three copies for tests.

Data Sheet 1
Sheet 2 of 3

RYAN ELECTRONICS
REPORT NO. 52065-2A

S/N 3

Primary Power 28 VDC 26 VDC 29.5 VDC (Delete Two)

Para.	Test	Reqmnt.	Measured 26 28 29.5
3.10	★(d) Power Supply	1.5 ~~[illegible]~~ MAX VDC	1.249 1.359 1.439
	(e) Filter Output	Varying Voltage	
		from 0.5 to 5.0 VDC	.2196 2.689
		No Ground Effect	OK
	(f) AGC	-0.6 to 0.0 VDC	-.539 to -0.099
		No Ground Effect	OK
	★(g) Reliability	Track ~~5 ± 0.2~~ 4.5 ± 0.5 VDC	+4.569
		No Ground Effect	OK
	★(h) Transmit Sig.	H.V. ON ~~-0.1 ± 0.05~~ .12 MAX VDC	-0.09
		H.V. OFF 0 ± 0.02 VDC	-0.01
		No Ground Effect	OK
3.11	Power Consumption	Oven OFF-less than 65 W.	61 W
		Oven ON-less than 80 W.	73 W

★- Limits changed by NASA request.
M.L. Olthoff

Data Sheet 1
Sheet 3 of 3

NOTE: Reproduce three copies for tests.

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RYAN ELECTRONICS

REPORT NO. 52065-2A

Test Performance
Eqpt. Model 520 Radar Altimeter
Serial No. 2
Primary Power 28 VDC ~~26 VDC~~ ~~29.5 VDC~~ (Delete two)
Ref. Para. 4.2

Date 1 Feb 1963
Test Engr. [illegible]
Witness [illegible]

Para.	Test	Reqmnt.	Measured
3.1	Trans. Freq.	1610 ± 5 MC	1611.1
3.2 (4) (c)	High Freq.	As Measured	1613.0
(d)	Low Freq.	As Measured	1610.0
(5) (b)	Bandpass	3.0 ± 0.5 MC	3.0
(e)	Center Freq.	Equal to 3.1 within 0.5 MC	1611.5
3.3 (3) (a)	Noise Ind.	0.2 to 0.4 VP/P	N/A
(d) 1.	Noise Insertion	As Measured (DB)	N A
2.	Correction	(1.75 DB at 1.610 KMC)	N A
3.	Cable Loss	As Calibrated	N A
5.	Noise Factor	Shall not exceed 8.0 DB	7.5 db
3.4	PRF	14400 ± 2 counts	14400
3.5	Pulse Width	From 0.8 to 1.1 us.	0.8
	Rise Time	Less than 0.1 us. (10% to 90%)	0.08 μs
	Decay Time	Less than 0.5 us. (90% to 10%)	0.18 μs
3.6	Trans. Power	5 KW Min.	6.5 KW
3.7	Clock Freq. (20 MC)	212.33664×10^6 ± 212 counts	212.33656
	Clock Freq. (2 CPS)	100 ± 2 counts	100
3.8	Vert. Velocity Tracking at 6KM/sec.	Ascending at	
		50 to 175 KM	OK
		175 to 400 KM	OK
		Descending at	
		400 to 175 KM	OK
		175 to 50 KM	OK
3.9	Overall System Accuracy	2411.63 ± 0.2034 us.	2411.55
		1459.18 ± 0.2034 us.	1459.1
		386.17 ± 0.2034 us.	386.05
3.10 (a)	Inhibit Signal	5 ± 0.5 VDC	4.8 VDC
		0 ± 0.5 VDC	0.2 VDC

Data Sheet 1
Sheet 1 of 3

NOTE: Reproduce three copies for tests.

6

S/N 2

Primary Power 28 VDC ~~26 VDC~~ ~~29.5 VDC~~ (Delete Two)

Para.		Test	Reqmnt.
3.10	(b)	Elapsed Time Word	5 ± 0.5 VDC Indicator ON 0 ± 0.5 VDC Indicator OFF

Measured

IND.	ON	OFF
2^0		[illegible]
2^1	[illegible]	
2^2	[illegible]	[illegible]
2^3	[illegible]	[illegible]
2^4	[illegible]	[illegible]
2^5	[illegible]	[illegible]
2^6	[illegible]	[illegible]
2^7	[illegible]	[illegible]
2^8	[illegible]	[illegible]

		Test	Reqmnt.
	(c)	Altitude Word	5 ± 0.5 VDC Indicator ON 0 ± 0.5 VDC Indicator OFF

IND.	ON	OFF
2^0	5.1	[illegible]
2^1	5.1	[illegible]
2^2	5.1	0.1
2^3	5.1	0.1
2^4	5.1	0.1
2^5	5.1	0.1
2^6	5.1	0.1
2^7	5.15	0.1
2^8	5.15	0.1
2^9	5.15	0.1
2^{10}	5.1	0.1
2^{11}	5.1	0.1
2^{12}	5.15	0.1
2^{13}	5.1	0.1
2^{14}	5.1	0.1
2^{15}	5.1	0.1
2^{16}	5.1	0.1
2^{17}	5.1	0.1

NOTE: Indicators 2^0 through 2^4 may jitter too much for an accurate voltage measurement. For these check that the voltage is present or absent.

NOTE: Reproduce three copies for tests.

Data Sheet 1
Sheet 2 of 3

RYAN ELECTRONICS

REPORT NO. 52065-2A

W itness - C H Henry

S/N 2

Primary Power 28 VDC ~~26 VDC~~ ~~29.5 VDC~~ (Delete Two)

Para.		Test	Reqmnt.	Measured
3.10	*	(d) Power Supply	1.5 ~~± 0.75 VDC~~ MAX	1.369
		(e) Filter Output	Varying Voltage from 0.5 to 5.0 VDC	.19 MIN 3.7 MAX
			No Ground Effect	OK
		(f) AGC	-0.6 to 0.0 VDC	-.1589
			No Ground Effect	OK
	*	(g) Reliability	Track ~~5~~ 4.5 ± ~~0.2~~ 0.5 VDC	4.84
			No Ground Effect	OK
	*	(h) Transmit Sig.	H.V. ON ~~-0.1 ± 0.05~~ .12 MAX VDC	-0.089
			H.V. OFF 0 ± 0.02 VDC	-0.009
			No Ground Effect	OK
3.11		Power Consumption	Oven OFF-less than 65 W.	61.7
			Oven ON-less than 80 W.	74.2

* Changed by NASA request.

M. F. Olthoff

Data Sheet 1
Sheet 3 of 3

NOTE: Reproduce three copies for tests.

RYAN ELECTRONICS

REPORT NO. 52065-1A

Test Performance
Eqpt. Model 520 Radar Altimeter
Serial No. 1
Primary Power 28 VDC 26 VDC 29.5 VDC (Delete two)
Ref. Para. 4.2

Date 3/29/63
Test Engr [illegible]
Witness C H Harris

Para.	Test	Reqmnt.	Measured
3.1	Trans. Freq.	1610 ± 5 MC	1612.6
3.2 (4) (c)	High Freq.	As Measured	1614.0
(d)	Low Freq.	As Measured	1610.9
(5) (b)	Bandpass	3.0 ± 0.5 MC	3.1
(e)	Center Freq.	Equal to 3.1 within 0.5 MC	1612.45
3.3 (3) (a)	Noise Ind.	0.2 to 0.4 VP/P	— ☆
(d) 1.	Noise Insertion	As Measured (DB)	— ☆
2.	Correction	(1.75 DB at 1.610 KMC)	— ☆
3.	Cable Loss	As Calibrated	— ☆
5.	Noise Factor	Shall not exceed 8.0 DB	7.3
3.4	PRF	14400 ± 2 counts	14400
3.5	Pulse Width	From 0.8 to 1.1 us.	0.81
	Rise Time	Less than 0.1 us. (10% to 90%)	0.1
	Decay Time	Less than 0.5 us. (90% to 10%)	0.25
3.6	Trans. Power	5 KW Min.	5.7KW
3.7	Clock Freq. (20 MC)	212.33664×10^6 ± 212 counts	212,33668
	Clock Freq. (2 CPS)	100 ± 2 counts	100
3.8	Vert. Velocity Tracking at 6KM/sec.	Ascending at 50 to 175 KM	OK
		175 to 400 KM	OK
		Descending at 400 to 175 KM	OK
		175 to 50 KM	OK
3.9	Overall System Accuracy	2411.63 ± 0.2034 us.	2411.6
		1459.18 ± 0.2034 us.	1459.1
		386.17 ± 0.2034 us.	386.1
3.10 (a)	Inhibit Signal	5 ± 0.5 VDC	4.6
		0 ± 0.5 VDC	0.2

Data Sheet 1
Sheet 1 of 3

NOTE: Reproduce three copies for tests.

☆ – Noise figure instruments not available, Sensitivity within limits, therefore acceptable.

M.L. Elkhoff

SIN!

RYAN ELECTRONICS
REPORT NO. 52065-1A

Witness - C.H. Hemm

Primary Power 28 VDC ~~26 VDC~~ ~~29.5 VDC~~ (Delete Two)

Para.		Test	Reqmnt.
3.10	(b)	Elapsed Time Word	5 ± 0.5 VDC Indicator ON; 0 ± 0.5 VDC Indicator OFF

Measured

IND.	ON	OFF
2^0	4.6	0.25
2^1	4.6	0.25
2^2	4.6	0.25
2^3	4.6	0.30
2^4	4.6	0.40
2^5	4.6	0.20
2^6	4.6	0.40
2^7	4.6	0.40
2^8	4.6	0.40

	Test	Reqmnt.
(c)	Altitude Word	5 ± 0.5 VDC Indicator ON; 0 ± 0.5 VDC Indicator OFF

IND.	ON	OFF
2^0	5.1	0.1
2^1	5.1	0.1
2^2	5.1	0.1
2^3	5.1	0.1
2^4	5.1	0.1
2^5	5.1	0.1
2^6	5.1	0.1
2^7	5.2	0.15
2^8	5.1	0.2
2^9	5.1	0.2
2^{10}	5.1	0.2
2^{11}	5.1	0.2
2^{12}	5.1	0.2
2^{13}	5.1	0.2
2^{14}	5.0	0.2
2^{15}	5.1	0.2
2^{16}	5.2	0.2
2^{17}	5.1	0.2

NOTE: Indicators 2^0 through 2^4 may jitter too much for an accurate voltage measurement. For these check that the voltage is present or absent.

NOTE: Reproduce three copies for tests.

Data Sheet 1
Sheet 2 of 3

S/N 1

RYAN ELECTRONICS

REPORT NO. 52065-1A

Witness - C. H. Hen

Primary Power 28 VDC ~~26 VDC~~ ~~29.5 VDC~~ (Delete Two)

Para.	Test	Reqmnt.	Measured 28 V	26 V	29.5
3.10	☆ (d) Power Supply	1.5 ~~VDC~~ MAX	1.347	1.240	1.419
	(e) Filter Output	Varying Voltage			
		from 0.5 to 5.0 VDC	+.339 to +4.919		
		No Ground Effect	OK		
	(f) AGC	-0.6 to 0.0 VDC	-0.0[illegible] to	-0.097	
		No Ground Effect	OK		
	☆ (g) Reliability	Track 4.5 ± 0.5 ~~5 ± 0.2~~ VDC	+4.789		
		No Ground Effect	OK		
	☆ (h) Transmit Sig.	H.V. ON −.12 MAX ~~[illegible]~~ VDC	−0.099		
		H.V. OFF 0 ± 0.02 VDC	−0.001		
		No Ground Effect	OK		
3.11	Power Consumption	Oven OFF-less than 65 W.	62 W		
		Oven ON-less than 80 W.	76 W		

☆ Changed by N.A.S.A. Request

M. L. Ollhoft

Data Sheet 1
Sheet 3 of 3

NOTE: Reproduce three copies for tests.